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Association

CURRENT CLIMATOLOGICAL ACTIVITY IN ALBERTA

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TECHNICAL SESSION

RECENT DEVELOPMENTS IN AUTOMATED DATA ACQUISITION

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We are living in the midst of the microelectronics revolution. The effects of this revolution will have an effect on our lives at least as profound as the industrial revolution had on the lives of our forefathers. The use of microelectronics to gather climatological data is in its infancy, but breakthroughs are occurring that will have a significant effect on the way we measure our environment.

Traditionally, climatological parameters have been recorded either manually, or by the method I have heard referred to as the little red line down the chart. These methods have simply become too expensive, and some managers have found that abstracting data from charts manually, and putting the data into machine readable form does not make sense any more. The first attempts to get away from the little red line down the chart method involved magnetic tape recording. Over the past fifteen years, we have seen marked progress in this area, and some failures. The efforts of the Campbell Scientific group in the area of magnetic tape recording have shown that this method can be a practical and reliable method of acquiring machine readable data. However, the system remains an electro-mechanical one, with the attendant problems of moving mechanical assemblies over a wide range of temperatures and environmental conditions.

One of the microelectronic chips that has become available is a device called an electrically programmable read only memory, or EPROM for short. This device is a small piece of silicon placed under a quartz window on a standard chip carrier. The device functions as a binary memory. It is made up of a great number of memory cells. When this device is exposed to high intensity ultra violet light through the quartz window, all the memory cells are set to binary state 1. A microprocessor connected to this device can access each memory cell, and read the contents of that cell. Many microcomputer operating systems are stored in EPROMs. By applying a certain sequence of voltages to the pins of the EPROM, the state of any particular memory location can be changed from 1 to a **0**. Therefore, a microprocessor can use these chips to store data. Of course, once a memory location has been changed to a 0, the microprocessor cannot change it back to a 1. The only way a memory location can be changed from a 0 to a 1 is to expose the entire chip to ultra violet light. You cannot selectively change an individual memory location back to a 1.

These chips are now available in various sizes. Common chips have 8 or 16 kilobits of memory cells available. Devices with 32 kilobits of

memory cells are now becoming available in quantity, with 64 kilobit devices available in prototype quantities. Electronic publications are now discussing the produon problems of 256 kilobit devices, and they should be available in quantity within the year. The price for a 16 kilobit chip is about $10 to $15.

In the latest issue of Electronics magazine, Motorola is advertising bubble memory modules that are capable of storing one million bits of data. These are devices to be used for circuit evaluation, and at the moment cost $500 U.S. each. I would guess that the price will drop to one tenth of that within five years. The bubble memory uses a different method of storing data than the EPROMs I have been discussing, but the effect is the same, that is, bubble memories can be used to permanently store data.

How much data can you store on a chip? One system now available will record a temperature reading every two hours for 170 days, without changing the chip, and using only four pen cells for power. When the instrument is serviced, you simply remove the EPROM, put a new one in, and tell the microcomputer in the instrument that you have changed the chip. The EPROM that has been removed can then be read by an EPROM reader that is available from many sources. For less than $100.00 you can buy one that will plug into your Apple computer, for instance. After the EPROM has been read, you can expose the chip to ultra violet light (EPROM erasers are available for less than $100.00), which will clear the memory. You can then test the chip by putting it back into your EPROM reader and verifying that all the memory locations are indeed set to 1. If the chip tests good, it can be placed in service again. If handled with due care, the EPROMs have a very long life, and can be erased hundreds of times. I suspect that mechanical factors, such as bent leads, will be the limiting factor in the chips life.

Other systems now available record the data in random access memory (RAM), which is volatile memory. That is, if power is removed from the chip, all data stored in that chip is lost. This problem can be overcome by putting a small battery in the electronics that will keep power on the memory chips constantly. These batteries will keep the memory alive for up to four years, even if you remove system power. Up to 64 kilobytes of memory can be easily addressed by existing systems, and with a little bit of ingenuity, double that size of memory can be addressed. When this system is used, the memory chips are not removed from the circuitry. Instead, you carry a small portable computer, such as an Epson HX-20, which will talk to the microprocessor in the recording system. You simply connect a cable to a port on the remote system, and the remote recording system microprocessor will transfer data to the portable computer. The data can be verified on site, recorded on magnetic tape, and/or printed on a small printer. Once the operator is satisfied that he has transferred the data successfully, then he can tell the recording system to clear its memory, and continue to record data.

The electronic circuitry required to measure and record one channel of data using the methods I have described above, can be put onto a printed circuit board of about 20 square inches. The microprocessors and other electronic devices used in these systems are all very low power devices, and will operate many months on a few flash light batteries. The circuits used are all rated to operate to -40°C, and most will operate to temperatures well below that. Housing and connectors account for a significant portion of the cost of a system. The prices for a typical unit will be $1,000 to $2,000, and I expect that price to continue to decrease slowly.

The electronics for these systems is now quite well defined, and most manufacturers are marketing a variation on a theme. The systems available now are limited in their capability, not by their electronics, but rather by their software. That is, the systems are capable of far more than their software will allow them to do. Most have very primitive, inflexible programs. Any changes in the program will require you to write out a detailed specification, send it off to the factory, wait three months or more, pay a hefty software charge, and hope that the software engineer interpreted your instructions properly. All too often, a hidden defect in the software will raise its ugly head under operating conditions, due to some interaction that the software engineer had not anticipated.

I anticipate that soon operating systems will be written that will make fuller use of the electronics, and allow the user significant flexibility in his system configuration. Data collection platforms available now have complete Forth operating systems built in. They allow you to process data on site, and interact with the data. There is no real reason why similar capabilities could not be built into electronic recording systems, and I anticipate that they soon will be.

The cost of these units will soon be such that they can compete on a dollar per dollar basis with such instruments as thermographs, and have the advantage of producing machine readable data. I can foresee the day when one of these types of systems will be built as part of a sensor, and not be an add on. For instance, I can see a device consisting of a simple thermometer and shield with a recording system built right into the assembly. Precipitation gauges will have the recorder built into them, as strip chart or punched tape recorders are integrated into them now. At present, the systems are add ons to existing gauges.

As I pointed out at the beginning of my talk, these are revolutionary devices. For that reason, they are difficult to market. It requires bold management to implement a revolutionary technology. It is far easier for a manager to carry on with his existing equipment and staff, than it is for him to implement a change. Bureaucratic structures often encourage this practice. I once submitted a budget with no increase in dollar value, but with a decrese in operating expenses that would be allowed by the purchase of capital equipment that would allow the

automation of certain processes. Management approved the decrease in operating budget, but would not allow the increase in capital expenditure.

INSTRUMENTATION OF A REMOTE METEOROLOGICAL STATION ON TURTLE MOUNTAIN

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Introduction

Turtle Mountain and the Frank Slide remain a major tourist attraction in the Crowsnest pass of southern Alberta. Disaster struck the town of Frank on April 29, 1903 when 30 million cubic metres of limestone slid from the east face of the mountain partially destroying Frank. Approximately 75 persons were killed. Slide debris travelled over 2 km across the valley and is still visible today from the Trans-Canada highway and Canadian Pacific Railway which now cut across the debris. The towns of Hillcrest and Bellevue have since developed at the base of the mountain.

Studies to determine the potential instability of the mountain have been carried out by Dr. Allen in 1930 and 1931. These studies were brought to the attention of the Department of the Environment of Alberta in 1980 by a geotechnical engineer at the University of Alberta. After years of investigating rock falls and rock stability, he suggested that studies be carried out to update the 1930-1931 monitoring network and to develop improved monitoring technology.

In response to this concern, the Department of Environment undertook to upgrade the existing monitoring network on the mountain which dates from 1932, and to institute several research projects to develop the technology needed to monitor potentially unstable rock masses. As a component of this series of research projects, a weather station was installed on the summit in the spring of 1983. This research is to define the climate and range of meteorological variables on top of Turtle Mountain and to provide the necessary atmospheric data to the concurrent research projets. The other projects include aerial photogrammetry of targets on the mountain peak, extensometer measurements of surface cracks and electronic distance measurements using laser technology from three miles away from the mountain.

This presentation will provide an overview of the project with an emphasis on the difficulties encountered in setting up and maintaining the measurement program. Future plans for the meteorological station will be presented.

Instrumentation

The main component of the weather station is a Campbell Scientific CR21 micrologger. This is a nine-channel computing data recorder. It is

fully programmable by the user through keyboard entry. Through the programming instructions, the user controls the frequency of measurement, basic analysis and output instructions. Linked to this is a modified cassette recorder for data storage.

Eight sensors are linked to the system. These include air temperature, relative humidity, barometric pressure, solar radiation, rock temperature, wind speed, wind direction and precipitation. These instruments have to be able to withstand constant exposure to subalpine arctic environmental conditions.

With the arrival of the equipment in February, 1983, a series of field tests were designed to become familiar with the system. Initially, the equipment was assembled on the roof of the Standard Life Centre in Edmonton. This test revealed a recurrent problem with the system. This was the freezing of the cassette recorder under winter conditions. Testing continued in April at the base of the mountain. In June the meteorological tower was relocated on the summit by helicopter. Siting the station on the mountain was difficult because of the rugged terrain and soft, weathered limestone. The final location is 10 metres from the crest, on a slope of 45 degrees, straddling a major crack on the west face of the mountain.

Data Collection and Analysis

With the appropriate programming instructions entered into the CR21 microprocessor, the input channels are scanned each minute and integrated hourly. The result is stored in an internal memory and subsequently, when the memory is full, written on to cassette tape. At a later date, the tape is read into the University of Alberta's computer for further storage and analysis.

The initial editing of the data files creates discrete monthly data sets. After this monthly and quarterly summaries of the meteorological data will be prepared. Special data sets can then be abstracted as requested by the individual users.

The installations and maintenance of a remote meteorological station in an environment like Turtle Mountain poses numerous problems. The major difficulty is the lack of easy access to the site. For at least eight months of the year, snow prohibits easy access. Thus, the system must be designed with a storage capability sufficiently large to handle data for this length of period. Alternatives to the tape recorder and cassette format have been explored; including the telemetry of the data to a radio at the Blairmore forestry station at the base of the mountain, and satellite communications. Telemetry systems which are compatible with the CR21 are under development. It is anticipated that this will be incorporated into the system this coming year. Even though the technology exists to use satellite communication systems, it is not

feasible with a large amount of data produced by this system.

A second problem to overcome was the extreme low temperatures to which the system is exposed. The micrologger can withstand severe temperatures, although it appears that the internal clock is affected by the cold and loses time slowly. In approximatey three months, the clock lost 33 minutes. The tape recorder, however, fails below approximately -5°C. It was necessary to shield it from extreme temperatures or to supply additional heat. Once again several options were considered. These included propane heaters and solar panels. Propane heaters have experienced trouble in other cold, remote locations and because of the access problems careful monitoring of the heater was not feasible. With the propane heater ventilation is necessary to remove excess water vapour and heat. Solar panels appear to be a viable option for the coming season to provide both heat and power to the system. It is still necessary to provide backup battery power for periods of low sunlight or snow covered panels. It was also noted that the cold temperatures drained regular alkaline batteries quickly. Additional battery packs composed of lithium-sulphur dioxide cells solved this problem.

In addition to these operating difficulties, the site presented several instrumental difficulties. For example, it proved difficult to accurately measure rainfall on a 45° slope when rain blows uphill constantly. Below the station, a 1 500 metre slope funnels wind upslope. Similarly, this uphill wind is difficult to measure with a standard horizontally mounted anemometer. In this case only the horizontal component of the wind is recorded. Snow covered sensors also pose a problem. Careful analysis of the data will show these periods of erroneous data and the data set can be corrected. Even common occurrences of lightning can be hazardous. In the recent past, lightning has struck the mountain in the vicinity of the station and damaged other monitoring equipment. The weather station is difficult to ground because of the low electrical conductivity of the limestone. As a precautionary measure a pointed lightning rod is in place on top of the tower to dissipate static electricity.

Short term solutions to the major problems of supplying heat to the tape recorder and micro-logger have been implemented to keep the system working this winter. The natural conditions of the site were utilized as much as possible. To modify the temperatures around the tape recorder, the natural insulating ability of snow was used. In November, 1983, the tape recorder was removed from the mast and enclosed in a foam insulated, water proof metal box. This box and an additional lithium battery pack, were lowered into a nearby crack into the mountain. This crack which extends for more than 30 m down into the mountain has a natural warm air vent in it. Wind blown snow accumulates in the crack covering the box providing a natural insulation. An additional battery pack for the CR21 was similarly insulated. When the site was visited in February, 1984, the CR21 was still operating despite severe winter temperatures in December and January. The additional problems of the uphill rain and wind and snow covered sensors have not been resolved yet.

Ongoing plans for the Turtle Mountain weather station are intended to make the system totally independent, and not requiring frequent servicing by the user. A newly developed solid state memory module is now being tested in the system. This alleviates the need for an on-site tape recorder, which is temperature-sensitive. This new module may retain 32 000 pieces of data. On the present system, this will last for two and one-half months only. The problem of site access still remains.

The option of data telemetry to the Blairmore forestry station is under further consideration for this coming season. This would allow real-time access to the system and permit the status of the system to be monitored continuously.

This season will see further improvements in the use of the CR21. It is intended this year to incorporate strain-gauges into the network of instruments monitoring the stability of the mountain. These are zero-displacement sensors able to detect small rock movements. The signal from the strain gauges will be input through the remaining analog channel on the CR21.

It is anticipated that the meteorological data recorded by the weather station will be required to fully analyze data from the other measurement projects. This includes the seismic data from the seismometers at the mountain base. Correlations between rainfall and barometric pressure and the seismic record will be investigated. On-site meteorological data will be useful in the analysis of the strain-gauge measurements. Past geotechnical engineering work has shown that the expansion and dilation of limestone is sensitive to humidity and temperature. The measuring instruments themselves, including the extensometer, are sensitive to thermal expansion and contraction. With on-site meteorological data the interpretation of these data will be enhanced.

The Turtle Mountain weather station has operated successfully for 9 months in extremely adverse conditions. The data generated will provide the basis for an ongoing climatological data base for the Turtle Mountain environment. In the short term, data will be used to support and analyze the data from the ongoing monitoring projects.

WINDS OVER A RURAL CENTRAL ALBERTA SITE AS OBSERVED WITH AN ACOUSTIC DOPPLER RADAR

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Introduction

Evaluation of pollutant emissions from existing and proposed industrial facilities is necessary for maintenance of acceptable ground level air quality. Assessments of air quality associated with elevated plumes, however, are based on wind speed and turbulence measurements made at ground level. It is now possible to measure wind speeds and turbulence at heights up to about 500 m above ground using acoustic sounding techniques.

An acoustic doppler radar manufactured by Xontech has been operating since mid-1982 at Alberta Environment's meteorological station, located about 5 km west of Ellerslie, Alberta. Discussion of the principles of radar operation may be found in the literature (i.e. Balser et al., 1976). The station is in an agricultural area characterized by cultivated fields and stands of trees. Time and space averaged data are available hourly at ten elevations ranging from 50 to 500 m for horizontal and vertical wind speeds, wind direction, and standard deviations of these parameters. An instrumented tower is used to collect wind information at 10 and 20 m near the ground to supplement data derived from the doppler radar.

This paper presents results of data analyses from the first year of acoustic doppler radar operation (1 September 1982 - 31 August 1983). A quality control was first instituted to ensure that radar information was reliable. This was necessitated by discrepancies between data collected by radar at the lowest levels and that collected by conventional tower mounted and tethered instruments. A detailed analysis was then performed with data deemed acceptable to ascertain the manner in which observed parameters changed with height.

Instrument Operating Efficiency

Stable and unstable atmospheres were defined in terms of night and daytime hours, respectively. Transition periods associated with neutral atmospheric situations were assumed to occur between 3 and 4 hours after sunrise, and between 1 and 2 hours before sunset. These assumptions were based upon time of breakup and formation of the nocturnal inversion, as shown by temperature data collected by Alberta Environment with an instrumented 92 m tower at Sherwood Park, near Edmonton. Neutral

conditions were also associated with periods characterized by 10 m level wind speeds in excess of 7 m s^{-1}.

Table 1 shows the number of hours of available data according to level and stability class for horizontal wind speed, wind direction and vertical wind speed. The reporting efficiency is given in brackets. The table shows, for example, that 679 hours of horizontal wind speed data are available for the 400 m level under neutral atmospheric conditions. This represents about 71 percent of all possible hours during neutral conditions. It is immediately apparent that reporting efficiency decreases with height. Efficiency at the higher levels is greater for unstable atmospheric conditions for all parameters except vertical speed. Reporting efficiencies for standard deviations of parameters were generally similar to values listed in Table 1.

Evaluation of Data Quality

Data collected at lower levels were evaluated by comparison with information available from the 20 m level of the meteorological tower. Tower information is collected at a precise elevation, and doppler radar data are representative of conditions through 50 m atmospheric layers. Comparisons, however, should be acceptable for purposes of assessing data reliability.

Quality of data was investigated by calculating correlation coefficients between data at various levels. It was reasoned that the coefficients should decrease with height. For example, information at the 20 m level should be most highly correlated with data from the 50 m level, less correlated with that from the 100 m level, and so on.

Table 2 presents correlation coefficients between wind speeds at various levels over the 12 month observational period. It indicates, for example, that the correlation coefficient between winds at the 20 and 150 m levels is 0.66. Table 2 shows that the 20 m winds were more highly correlated with the 150 m winds than those at either the 50 or 100 m levels. Wind speeds at the 50 m level correlate poorly with winds at all other levels. Speeds at the 100 m level correlate with those at 150 m only slightly better than do 20 m winds. The type of behaviour revealed in Table 2 suggests that reported winds for the 50 and 100 m levels were not reliable. This conclusion was further tested by studying wind rose patterns and variations of wind speeds with heights.

Figure 1 presents wind roses for the 20 and 50 m levels. Winds at the higher level appear to reflect a veer of about 180 degrees in direction, and greatly reduced speeds. Such behavious cannot be explained in terms of known atmospheric phenomena. Figure 2 shows vertical variations in annual median wind speeds for profiles reaching up to 500 m. The solid line is the expected profile based upon a power law relation with a value for P of 0.25, appropriate to slightly stable atmospheres. (The wind

speed power law relation is of the form $U_1 = U_2 (Z_1/Z_2)^P$ where U and Z are wind speed and height, respectively, at two levels and P is a constant). Reported wind speeds for the 50 and 100 m levels depart very markedly from expected behaviour. Of some interest is the fact that wind speeds at the 200 m level are less than those at the 150 m level.

It appears from the above analysis that doppler winds reported for 50 and 100 m levels were not acceptable.

Variation of Parameters at Selected Levels

Figure 3 compares wind roses at the 20, 200, 350 and 500 m levels. Light southeasterly winds were observed most frequently at the 20 m level. Winds were much stronger and predominantly from the northwest at the 500 m level.

The cumulative frequencies of vertical wind speeds observed at 200, 350 and 500 m levels are shown in Figure 4. Observed magnitudes of both updrafts (positive W) and downdrafts (negative W) tended to increase with height. It is of interest to note that median values of W were slightly positive (about 0.1 m s^{-1}).

Variation of Horizontal Parameters with Height

Variation of wind speeds, wind direction and turbulence with height were evaluated by stability from homogeneous data profiles. Homogeneous data profiles contain data at all levels up to 500 m, with the 50 m and 100 m levels excluded.

Horizontal Wind Speeds

Median horizontal wind speeds were examined as a function of height for each stability class. Values of exponent for the wind speed power law function, P, were calculated for each observed profile using least square techniques. Distributions of resulting P values are illustrated in Figure 5. Values varied from about -0.20 to about 0.80. Medians for unstable, neutral, and stable atmospheric conditions were 0.10, 0.17 and 0.28, respectively. Negative values of P, indicating a tendency for wind speed to decrease with height, occurred about 4, 5 and 12 percent of the time for stable, neutral, and unstable conditions, respectively.

Wind Direction

Median differences in wind directions from 10 m values are shown in Figure 6 as a function of height. Changes occurred more rapidly near the ground and were largest under stable atmospheric situations.

Figure 7 presents cumulative frequencies of wind direction changes between the 250 and 10 m levels. Direction changes increased with stability. Median values were about 5, 10 and 20 degrees for unstable, neutral and stable atmospheres, respectively. About 30% of direction changes were negative indicating a backing of wind with height.

Turbulence

Atmospheric turbulence is caused by fluctuations in wind speed and direction. Standard deviations of horizontal and vertical wind speed, σ_U and σ_W, are measures of horizontal turbulence in the direction wind, and vertical turbulence, respectively. Horizontal turbulence perpendicular to wind direction, σ_V, was estimated from the relationship $\sigma_V = \sigma_\theta$, where U is wind speed and σ_θ is standard deviation of wind direction. In evaluations of plume dispersion, σ_V and σ_W, are related to horizontal and vertical plume spreads, respectively.

Dependences of horizontal and vertical plume spread parameters on height in the lower atmosphere are theoretically similar in stable and neutral conditions (Hanna et al., 1982). This means that ratios of σ_W to σ_V at each level should be unity).

Table 3 presents median σ_U, σ_V and σ_W for each level by atmospheric stability. Values of σ_U and σ_V increase with height, and values of σ_W decrease. Values are greatest in unstable conditions. Further evaluation revealed that data in Table 3 vary exponentially with height.

Figure 8 shows the ratio of horizontal to vertical plume spread parameters as a function of height based on derived exponential relationships. Ratios near the ground are close to unity as predicted by theory. However, contrary to theory, ratios decrease sharply with height above ground.

Discussion

Analyses of doppler wind data have shown a number of interesting features.

Winds observed at the 50 and 100 m levels were shown to exhibit behaviour which was unexplainable in terms of known atmospheric phenomena. This behaviour has been attributed by the doppler radar manufacturer to software difficulties which have subsequently been corrected.

Both vertical and horizontal winds tended to increase with height. Median vertical winds were slightly positive. Median values of P for the power law function applied to horizontal winds were found to be 0.28,

0.17 and 0.10 for stable, neutral and unstable atmospheres, respectively. These are consistent with values found by other investigators (Touma, 1977) from wind observed at lower elevations.

Wind directions generally tended to veer with height. Wind backed with height, however, for an appreciable portion of the time (30%). Direction changes were greatest near the ground and largest under stable conditions. Magnitudes of the veer, between 10, 15 and 30 degrees, respectively. These were consistent with values reported in the literature (Smith, 1973).

Longitudinal and transverse components of turbulence were found to be nearly equal. Near ground level the longitudinal component is usually about 30% larger than the transverse component.

Increases in horizontal components of turbulence were found to be nearly equal. Near ground level the longitudinal component is usually about 30% larger than the transverse component.

Increases in horizontal turbulence with height were unexpected on the basis of accepted theory. It appears on reflection, however, to be a reasonable phenomena. It is natural that vertical turbulence will decrease with distance above the ground where it is engendered by mechanical and thermal forces. As vertical mixing decreases, the exchange of momentum between various air layers will also decrease. These air layers are consequently more free to respond to small variations in local pressures which might be induced, for example, by gravity waves. The greater freedom of response results in greater oscillations in wind direction. The same phenomena is observed near the ground under stable, light wind situations when mechanically and thermally induced vertical turbulence will be small. Under these circumstances horizontal turbulence becomes very large (Leahey and Halitsky, 1973; Sagendorf and Dickson, 1976).

The tendency for ratios of vertical to horizontal turbulence (i.e. σ_W/σ_V) at elevated levels to be smaller than expected has important consequences to plume elevation. It means that high elevated plumes from sources such as thermal power plants will be more dilute upon reaching the ground than previously thought.

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Table 1

FREQUENCY (IN HOURS) OF ALL OBSERVED PARAMETERS BY ATMOSPHERIC STABILITY. OBSERVED FREQUENCIES AS PERCENTAGES OF TOTAL TIME FOR EACH STABILITY CLASS ARE IN PARENTHESES

Parameter	Level (m)	Atmospheric Stability Stable		Neutral		Unstable	
Horizontal Speed (U)	10	5236	(97)	943	(98)	1880	(97)
	20	5272	(98)	950	(88)	1895	(98)
	50	5243	(98)	911	(95)	1898	(98)
	100	5247	(98)	796	(83)	1836	(95)
	150	5255	(98)	890	(93)	1914	(99)
	200	5304	(99)	907	(94)	1927	(99)
	250	5133	(95)	895	(93)	1923	(99)
	300	4944	(92)	851	(89)	1890	(97)
	350	4556	(85)	776	(81)	1852	(95)
	400	4000	(74)	679	(71)	1748	(90)
	450	3278	(61)	552	(57)	1595	(82)
	500	2280	(42)	395	(41)	1289	(66)
Direction (θ)	10	5232	(97)	943	(98)	1880	(97)
	20	5140	(96)	912	(95)	1866	(96)
	50	5244	(98)	911	(95)	1898	(98)
	100	5247	(98)	796	(83)	1836	(95)
	150	5255	(98)	890	(83)	1914	(99)
	200	5304	(99)	907	(94)	1927	(99)
	250	5133	(95)	895	(93)	1923	(99)
	300	4944	(92)	851	(89)	1890	(97)
	350	4556	(85)	776	(91)	1852	(95)
	400	4000	(74)	679	(71)	1748	(90)
	450	3278	(61)	552	(57)	1595	(82)
	500	2280	(42)	395	(41)	1289	(66)
Vertical Speed (W)	50	1	(0)	0	(0)	0	(0)
	100	4884	(91)	695	(72)	1022	(53)
	150	4882	(91)	694	(72)	1021	(53)
	200	4879	(91)	693	(72)	1018	(52)
	250	4846	(90)	691	(72)	1015	(52)
	300	4736	(88)	675	(70)	1006	(52)
	350	4439	(83)	638	(66)	986	(51)
	400	4031	(75)	586	(61)	956	(49)
	450	3505	(65)	517	(54)	892	(46)
	500	2958	(55)	450	(47)	810	(42)

Table 2

LINEAR CORRELATION COEFFICIENTS BETWEEN
WIND SPEEDS AT INDICATED LEVELS

Height (m)	Height (m) 20	50	100	150	200	250	300
50	0.10						
100	0.54	0.39					
150	0.66	0.31	0.71				
200	0.63	0.35	0.71	0.86			
300		0.33	0.65	0.85	0.88	0.94	
350			0.62	0.82	0.84	0.91	0.96
400				0.77	0.79	0.85	0.89
450					0.76	0.81	0.85
500						0.77	0.83

Table 3

MEDIAN VALUES (m s^{-1}) OF TURBULENCE COMPONENTS AT EACH LEVEL BY
ATMOSPHERIC STABILITY FOR HOMOGENEOUS PROFILES

Stability	σ_U			σ_V			σ_W		
	S	N	U	S	N	U	S	N	U
Level (m)									
150	.9	.8	1.1	.9	.8	1.0	.5	.6	.7
200	1.0	.9	1.2	.9	.8	1.1	.4	.5	.6
250	.9	.9	1.2	.9	.9	1.2	.4	.4	.5
300	.9	.9	1.3	1.0	.9	1.3	.3	.4	.5
350	1.0	.9	1.4	1.1	1.0	1.4	.3	.4	.5
400	1.1	1.1	1.5	1.3	1.2	1.5	.3	.4	.4
450	1.3	1.2	1.7	1.6	1.5	1.7	.3	.3	.4
500	1.4	1.4	1.9	1.7	1.7	2.0	.2	.3	.4
Number of Observations	1820	310	1150	1745	305	1140	2342	328	652

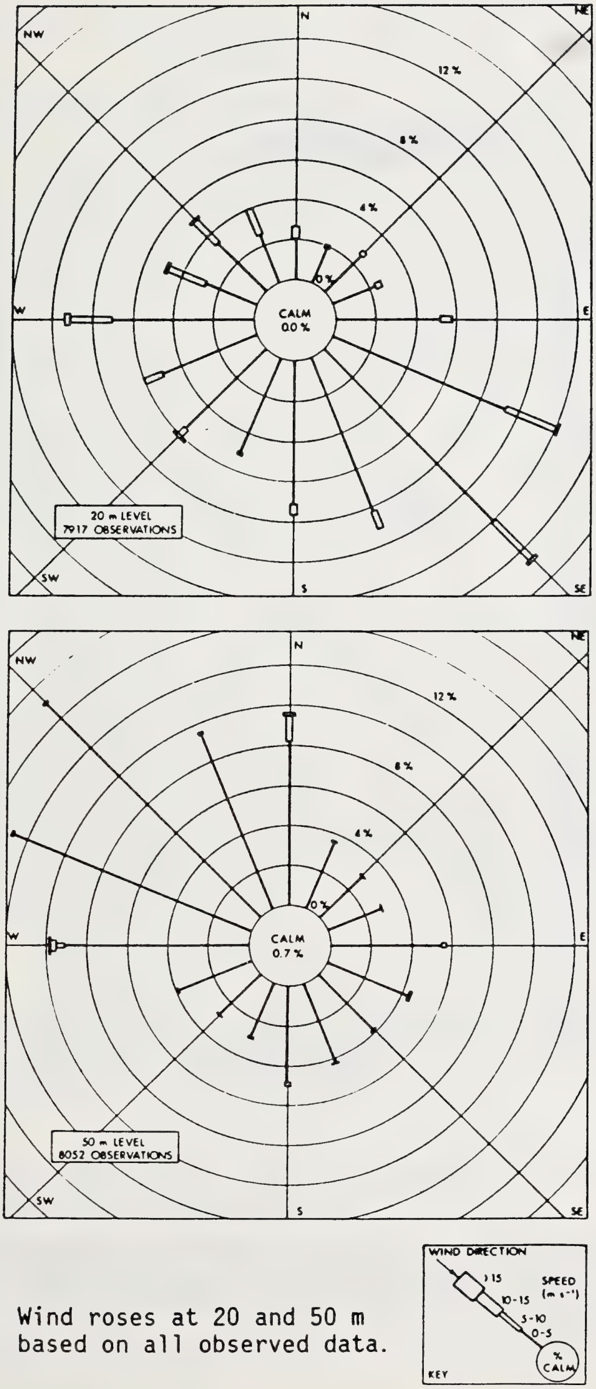


Figure 1. Wind roses at 20 and 50 m based on all observed data.

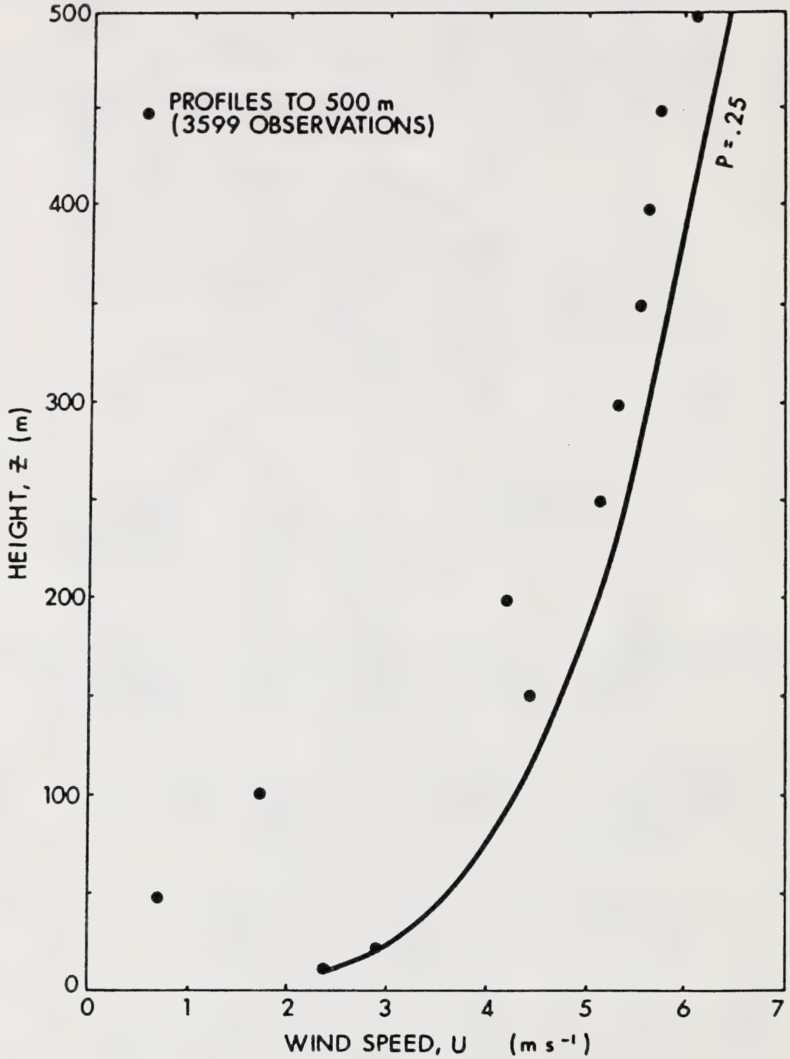
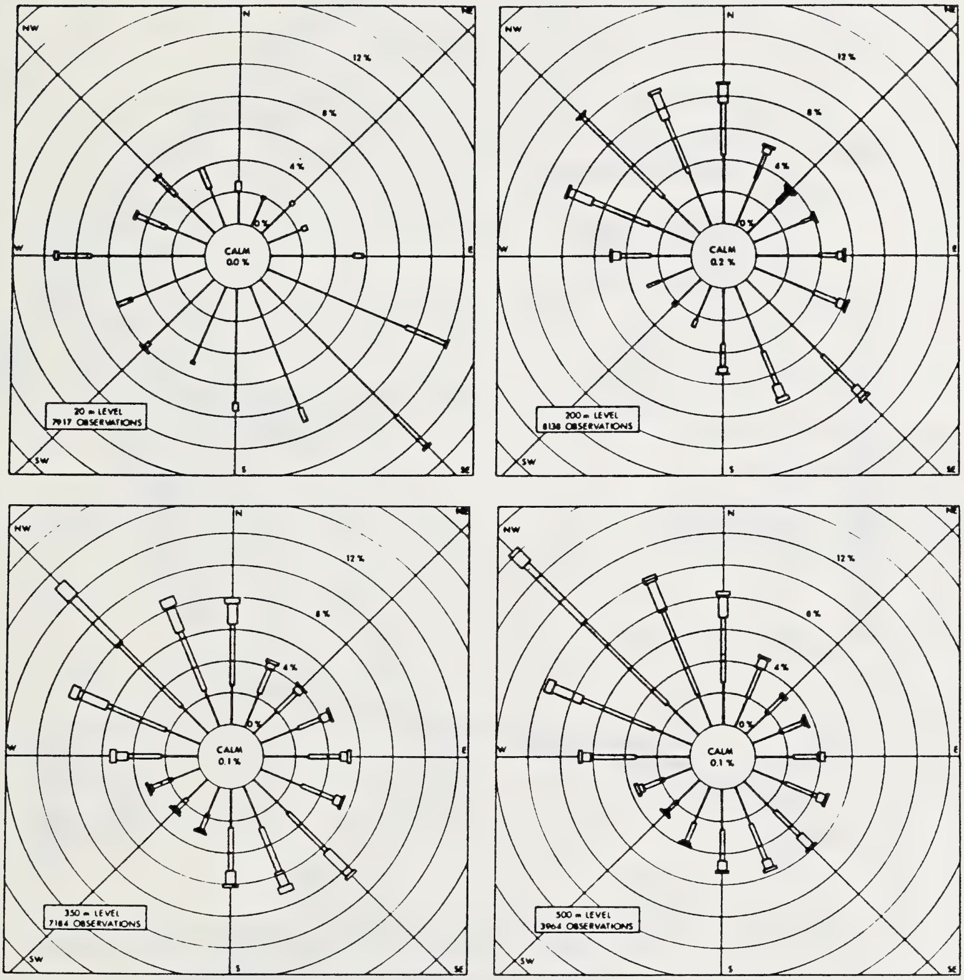


Figure 2. Median wind speeds as a function of height for all profiles reaching 500 m. A power law curve using an exponent of 0.25 (slightly stable atmosphere) is also shown.



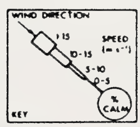


Figure 3 Wind roses at 20, 200, 350 and 500 m based on all observed data.

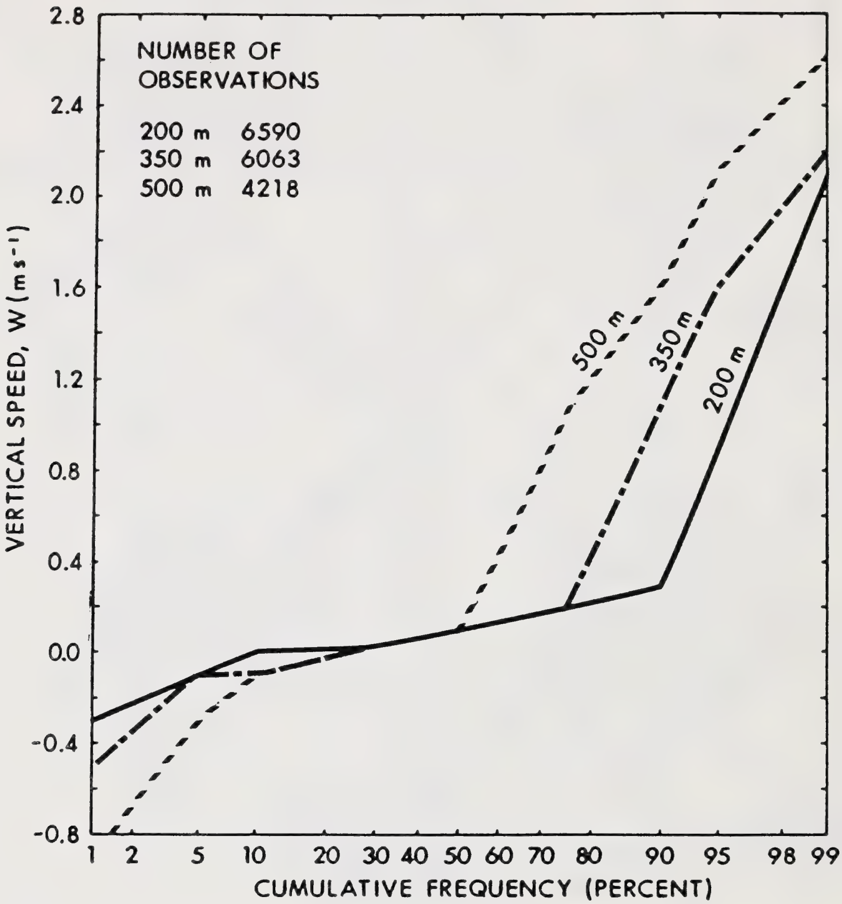


Figure 4 Frequency distribution of vertical wind speeds at 200, 350 and 500 m based on all observed data.

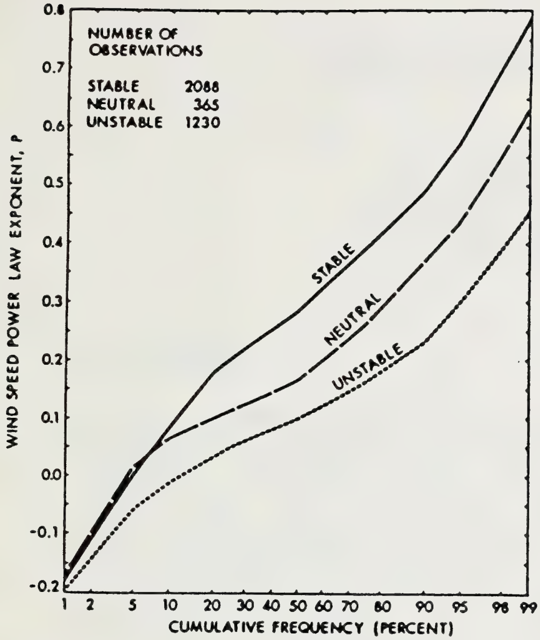


Figure 5 Frequency distribution of power law exponent P.

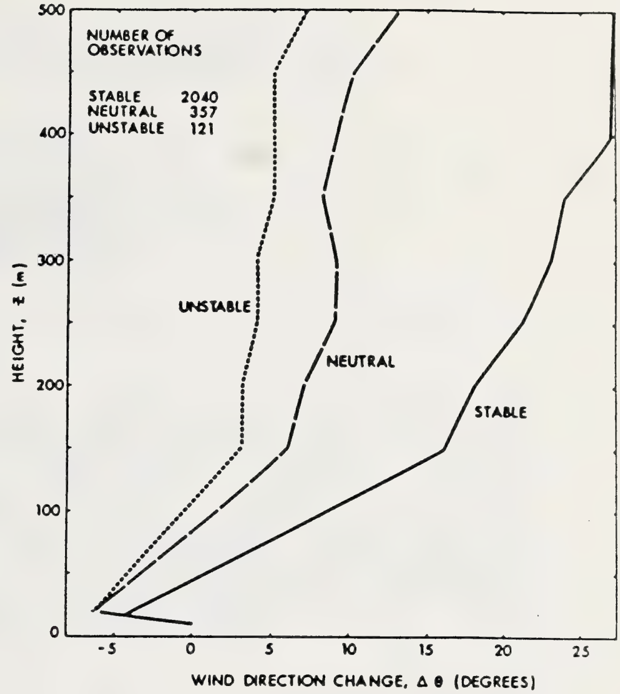


Figure 6 Median change in wind direction compared with that at 10 m as a function of height for different atmospheric stability conditions.

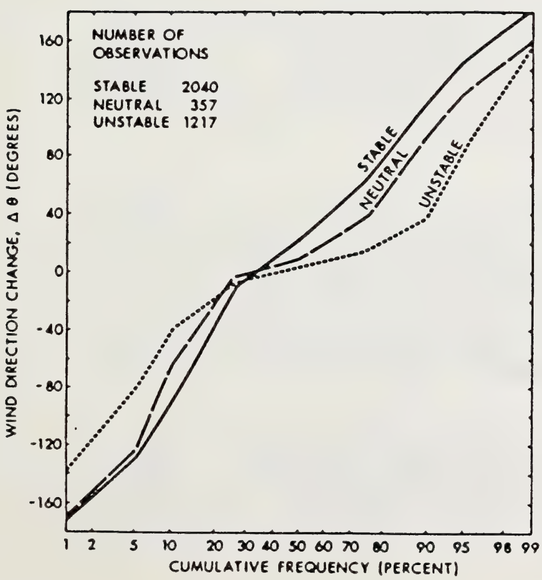


Figure 7 Frequency distribution of differences in wind direction between 250 and 10 m.

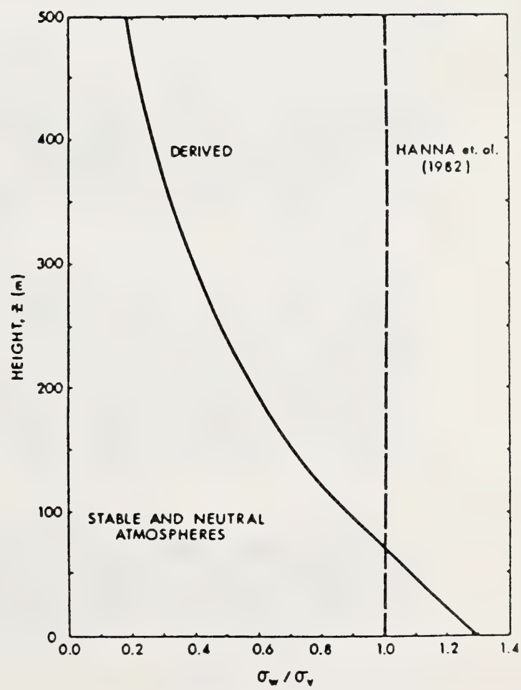


Figure 8 Derived and theoretical expressions for the ratio σ_W/σ_V as a function of height.

CLIMATE SERVICES IN WESTERN REGION

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Atmospheric Environment Service
Environment Canada

Introduction

Western Region Climate Services has increased the utilization of computerized techniques, analyses and graphics over the past few years. Automated procedures have been implemented to quality control climatological data; read, decode and store Alberta Forestry data in real time for forecasting and climatological purposes; and quality control of soil, pan evaporation and sunshine data. Additionally, graphic outputs can be produced for storm rainfalls, monthly precipitation and departures from normal and network maps. These have been reported to the Alberta Climatological Association workshops from 1981 to 1983.

This paper discusses Western Region's capabilities in climatological analyses utilizing the AES computer in Downsview and the National Digital Climatological Archive. Additionally, AES policy on non-standard data archiving is discussed.

AES Downsview Computing Centre

The AES Downsview computer was installed in September, 1980. The system consist s of a National Advanced Systems Model AS/6-2 built by Hitachi Corporation. The AS/6-2 is functionally compatible with the IBM 370 series and has performance roughly equivalent to an IBM Model 3032. The system configuration is shown in Figure 1.

As the AS/6 is functionally compatible with the IBM 370, the major operating system software is standard IBM products. The operating system is MVS (Multiple Virtual Storage) as the system control program with JES2 (Job Entry Subsystem 2) to control user programs. Timeshare users have the WYLBUR and TSO interactive packages to enter, edit, compile, submit, and retrieve jobs from the batch system. Other major software packages inculde SAS, DISSPLA, IMSL library, etc.

AES Western Region accesses the AS/6 utilizing an HP intelligent terminal through a dedicated connection (Figure 2). Jobs can be output in Downsview or retrieved at the local terminal for printing, further processing and plotting.

FIGURE 1: AES DOWNSVIEW COMPUTER SYSTEM CONFIGURATION

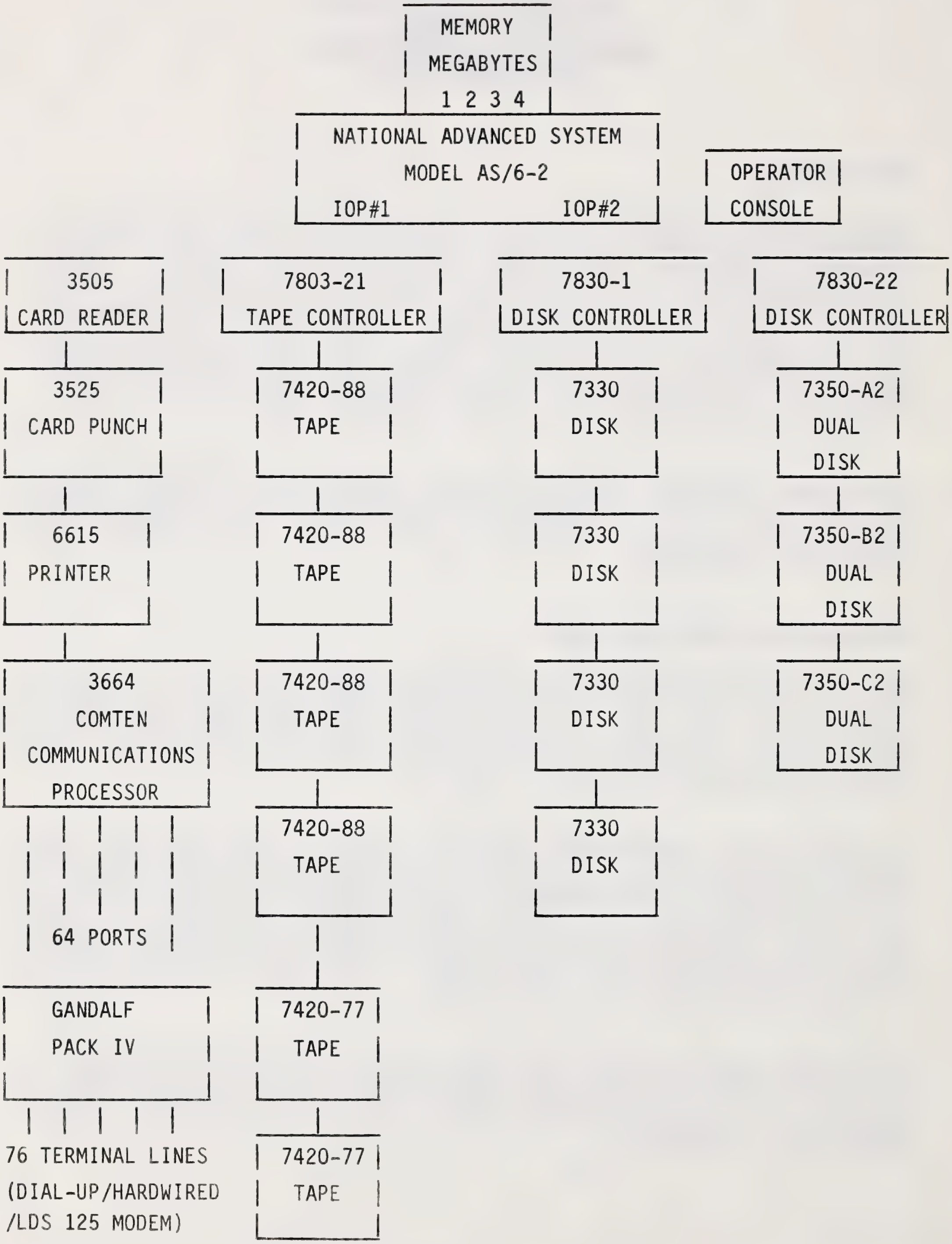
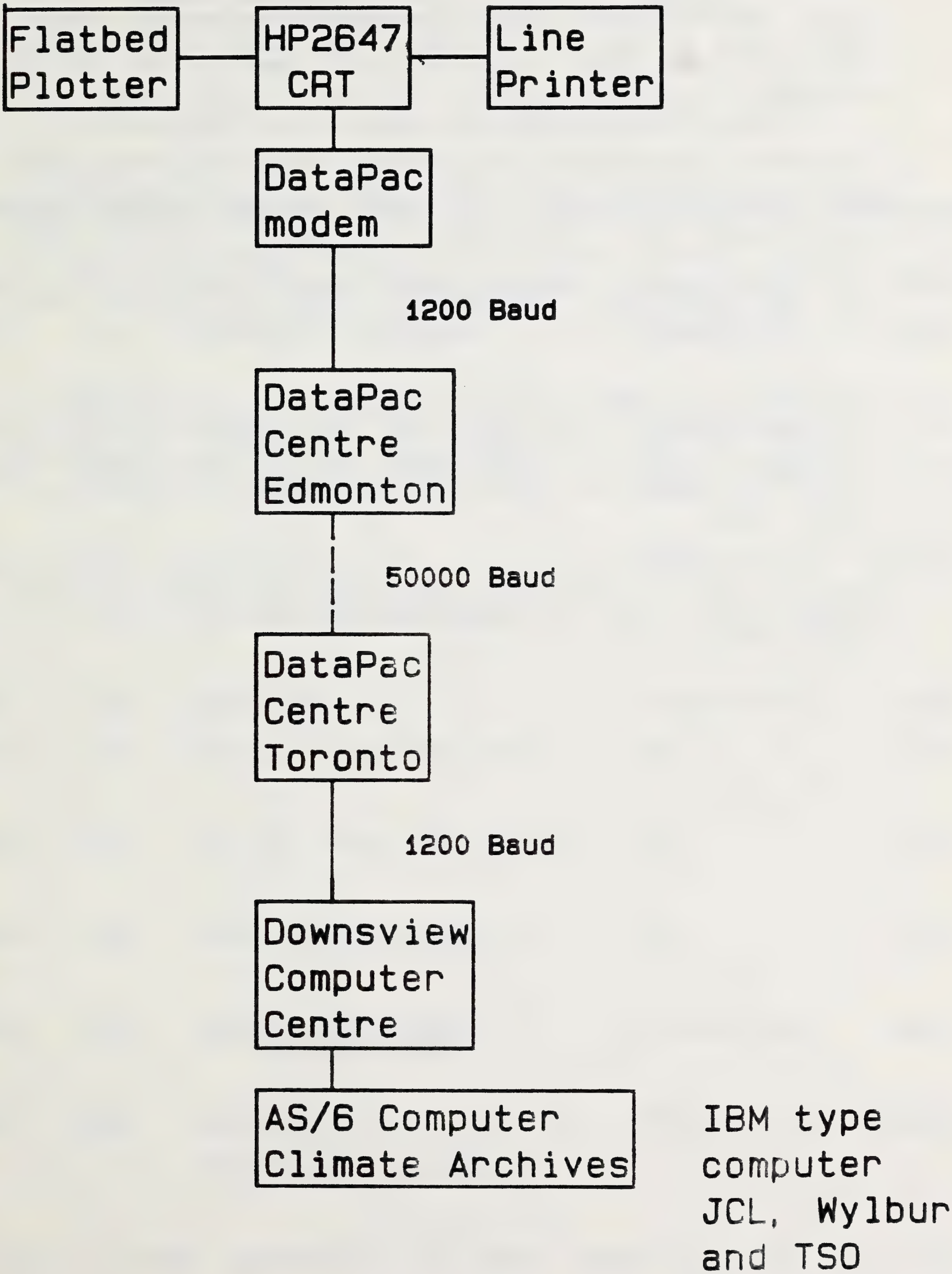


FIGURE 2

AS/6 Downsview Computer Access



National Climatological Archive

Several types of climatic data are contained in the National Archive; namely, paper, micrographic and digital. The latter is of increasing importance and interest to the scientific community and will be discussed.

The National Climatological Digital archive is divided into three formats based on observational frequency [hourly (HLY), daily (DLY), and monthly (MLY)], with each different climatological parameter identified by a unique element number. Some historic data [upper air, marine, tower, freeze-up, break-up, Fischer-Porter (F-P) precipitation, sea ice and deep water wave] do not lend themselves to the above format and are retained n their card image format. Development is taking place to convert upper air and F-P precipitation to a new format at the present time.

The archive file organization is shown in Table 1, and is dependent on the type and amount of data. The archive files are organized by station, province, all stations in Canada, and by district. The district organization is basically by river basin and is shown in Figure 3. The district code corresponds to the first three digits of the climatological station number.

Almost all data in the digital archive have been quality controlled. Updates are usually done on an annual basis but data are available prior to the updates.

TABLE 1

Canadian Climate Data

ARCHIVE FILE ORGANIZATION

Format	System	Type of Data	Organization	Stations
HLY	01	Surface Hourlies	Station	380
HLY	01	Cloud Layers	Station	380
DLY	03	Rate of Rainfall	Province	772
HLY	03	Rate of Rainfall	Province	772
DLY	04	Daily Climatological	District	5200
HLY	10	Sunshine	Province	426
HLY	11	Solar Radiation	ALL	64
DLY	12	Soil Temperatures	ALL	82
DLY	13	Pan Evaporation	ALL	217
HLY	15	Wind Mileage	District	400
MLY	S4	Monthly Climatological	District	5800

* All data updated to Dec 1982 as of Jan 84

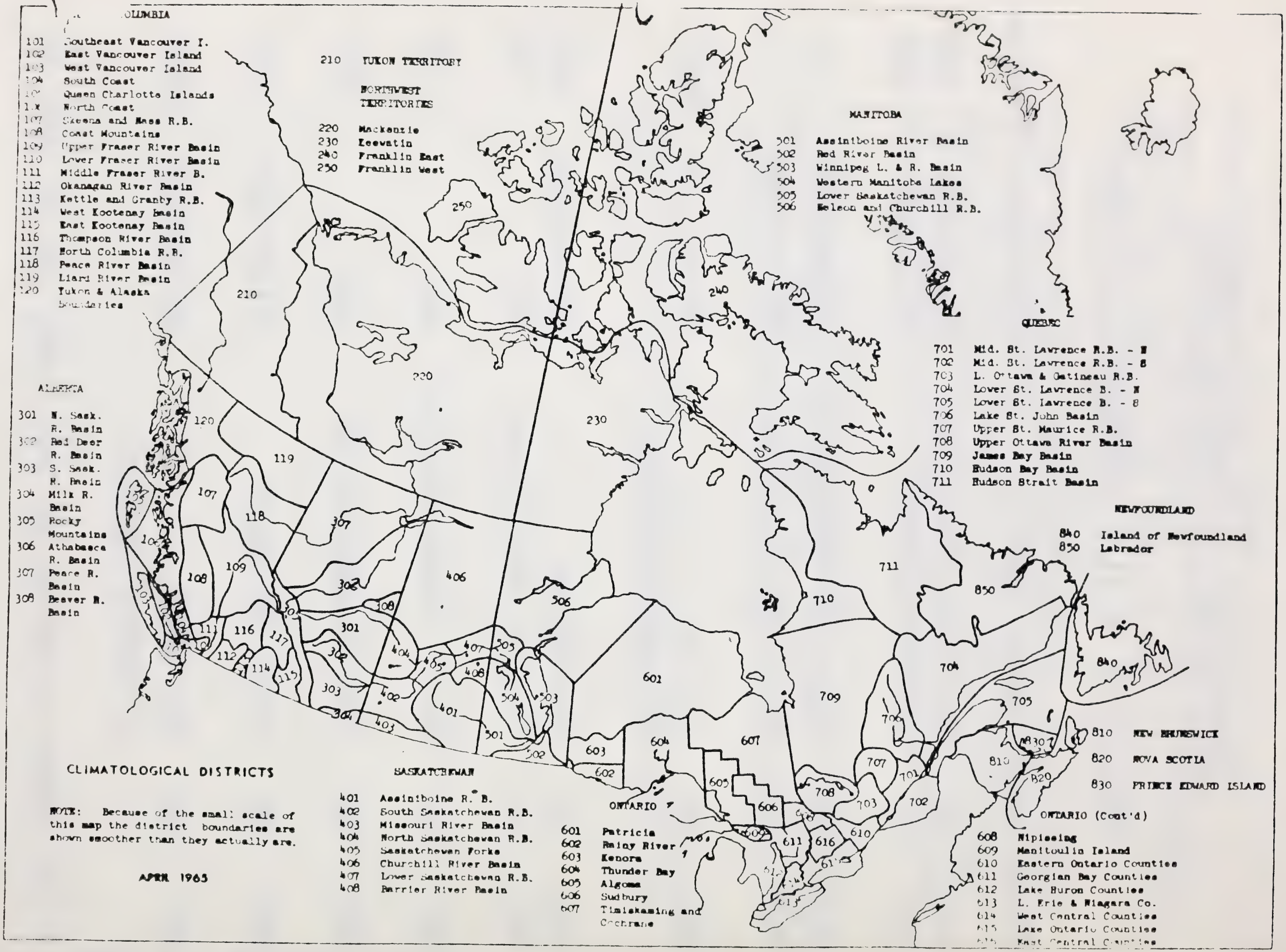


FIGURE 3: Climatological Districts

General Climate Analysis Programs

The Canadian Climate Centre has a number of General Report Programs (GRPs) available which output custom analyses of data from the digital archive. These programs allow quick and economical access to archival data (or derived data) by generating statistical summaries and selective data listings.

The programs are subdivided depending on the observing frequency of the input data:

Card image input	- GRPØxx
Hourly observations	- GRP1xx
Daily observations	- GRP2xx
Monthly observations	- GRP3xx
Archive preparatory programs	- GRFxxx

A brief description of various GRP programs is contained in Tables 2 to 5.

Documentation on the form and options for report programs including examples are available from Western Region Climate Services.

Table 2

CARD IMAGE GENERAL REPORT PROGRAMS (GRPs)

GRP002	To select and list stations by province, latitude, longitude, observing program and date opened.

Table 3

HLY ARCHIVE FORMAT GRPs

GRP102	Day/hour matrix of one selected element.
GRP102A	Day/hour matrix of multiple selected elements.
GRP103	Diurnal means.
GRP104	Absolute or percentage frequency matrix of "X" (1-15) classes and "Y" (1-50) classes.
GRP105	Absolute or percentage frequency of wind speed and direction.
GRP106	Days with specified conditions.
GRP107	Diurnal frequencies of from 1-40 combinations of elements.
GRP108	To identify by oneset date and length the duration from 1-40 conditions (requres GRP110 or GRP111).
GRP110	To list the duration records output by GRP108.
GRP111	Frequency by duration length within month, for conditions defined by GRP108 or GRP201.
GRP114	Inventory of specific HLY data formats.
GRP115	STAR stability program - wind speed and direction analysis grouped by Pasquill's stability classes.
GRP116	Frequency by month of dry bulb temperature, wet bulb temperature or humidex.
GRP118	To assemble all elements (except cloud layer) and display the observations on one line.
GRP119	Average wind speed and percentage frequency by wind direction and hour.

Table 3 (continued)

GRP121	Absolute or percentage frequencies of 1-50 classes of any element.
GRP122	To produce a Gumbel Return Period statistic in report from using records passed from GRF106.
GRP123	Frequency of occurrence of selected ranges of element X for selected hours with corresponding means, extremes and standard deviations of element Y.

Table 4

DLY ARCHIVE FORMAT GRPs

GRP200	Inventory of standard elements in DLY format.
GRP201	To identify by onset date and length, the duration of from 1-40 conditions.
GRP202	Daily, monthly and annual degree days above or below a given temperature.
GRP203	Means, extremes and standard deviations of daily maximum temperature, minimum temperature, mean temperature and 24-hour precipitation.
GRP208	To compute extreme 1-10 day rainfall or precipitation amounts. Also computes 2, 5, 10, 25 and 100 year return for 1-5 day extremes.
GRP210	Means, extremes and standard deviations of a selected element.
GRP211	Absolute or percentage frequency from 1-50 classes of any element.
GRP212	Month/day matrix of a selected element.
GRP213	To locate the gaps of a certain size, as specified by a control card, and list them in detail and/or in summary.

Table 5

MLY ARCHIVE FORMAT GRPs

GRP301	Inventory of MLY archive format.
GRP302	Absolute or percentage frequency from 1-50 classes of any element.
GRP303	Calculates means, extremes and standard deviations.
GRP304	Year/month matrix of one selected element.

Climatological Analysis Systems

Various climatological analysis packages have been produced by the Hydrometeorology Division, Canadian Climate Centre, and are available for use by anyone with a valid AS/6 users account. The systems were designed to be "user friendly", flexible and to produce high quality graphics (including colour), and tables for immediate use in reports. The analysis packages available are marine statistics (MAST), land statistics (LAST), gridded atmospheric statistics (GASP), duration statistics (DUST), and contour analysis (CONAN).

The purpose of MAST is to access a data base of transient ship observations in TDF11 format and produce statistical analyses on met eorological and oceanographic parameters.

MAST can produce exceedance listings, observation counts by climatological variable, basic statistics, univariate and bivariate frequency analysis and directional plot roses. Examples of MAST graphical output are presented in Figures 4 to 7. The map in the upperright corner denotes the analysis area.

LAST accesses the hourly Canadian Climatological digital archive and converts the data to a format compatible with MAST. To obtain statistical analyses, the data set created by LAST must be used in a MAST session. The outputs produced are the same except oceanographic parameters are excluded. Data is generally available for the time period 1953 to 1982, however, this is dependent upon the stations' observing period.

GASP produces tabular and graphical analyses similar to MAST but for indivudal or groups of gridded data for a specified area. Grid points may be analysed separately or combined into one analysis describing a large area. The gridded data available are surface and upper-air from the Naval Environmental Data Network (NEDN).

DUST accesses TDF11 or MAST-2 format data as input and provides the user with durations, extreme value analysis, extreme value analysis of durations, and contour maps of statistics for several locations.

CONAN is a contouring analysis package to provide mapping capabilities for the above climatological analysis packages.

Computer costs for analyses are dependent on the type and amount of data, output and graphics utilized. Minimum charges for a MAST/LAST run, excluding graphics, ranges from \$50 - \$100 (approximately \$10 per CPU minute).

ENVIRONMENT CANADA
ATMOSPHERIC ENVIRONMENT CANADIAN CLIMATE CENTRE

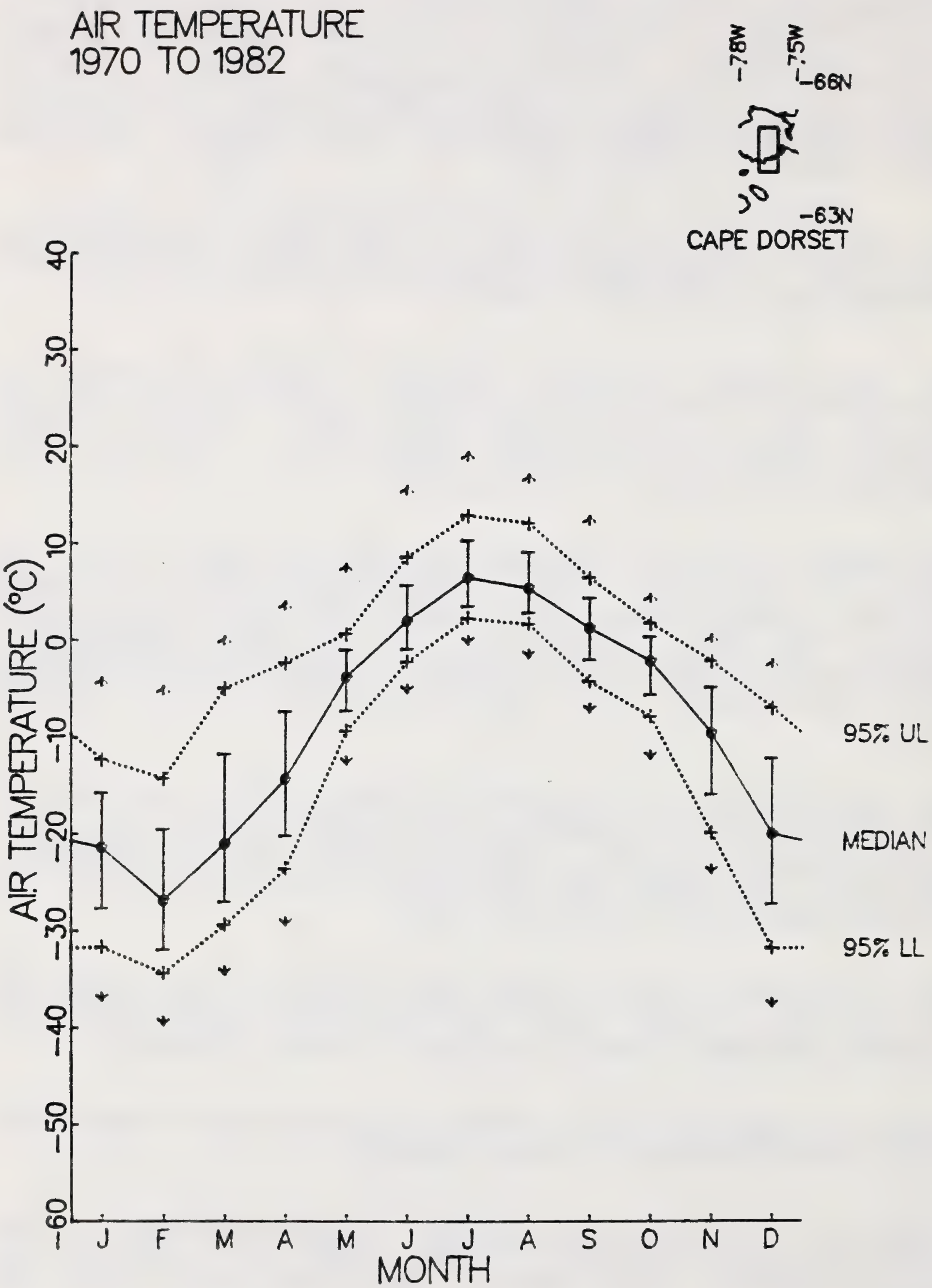


FIGURE 4

ENVIRONMENT CANADA
ATMOSPHERIC ENVIRONMENT CANADIAN CLIMATE CENTRE

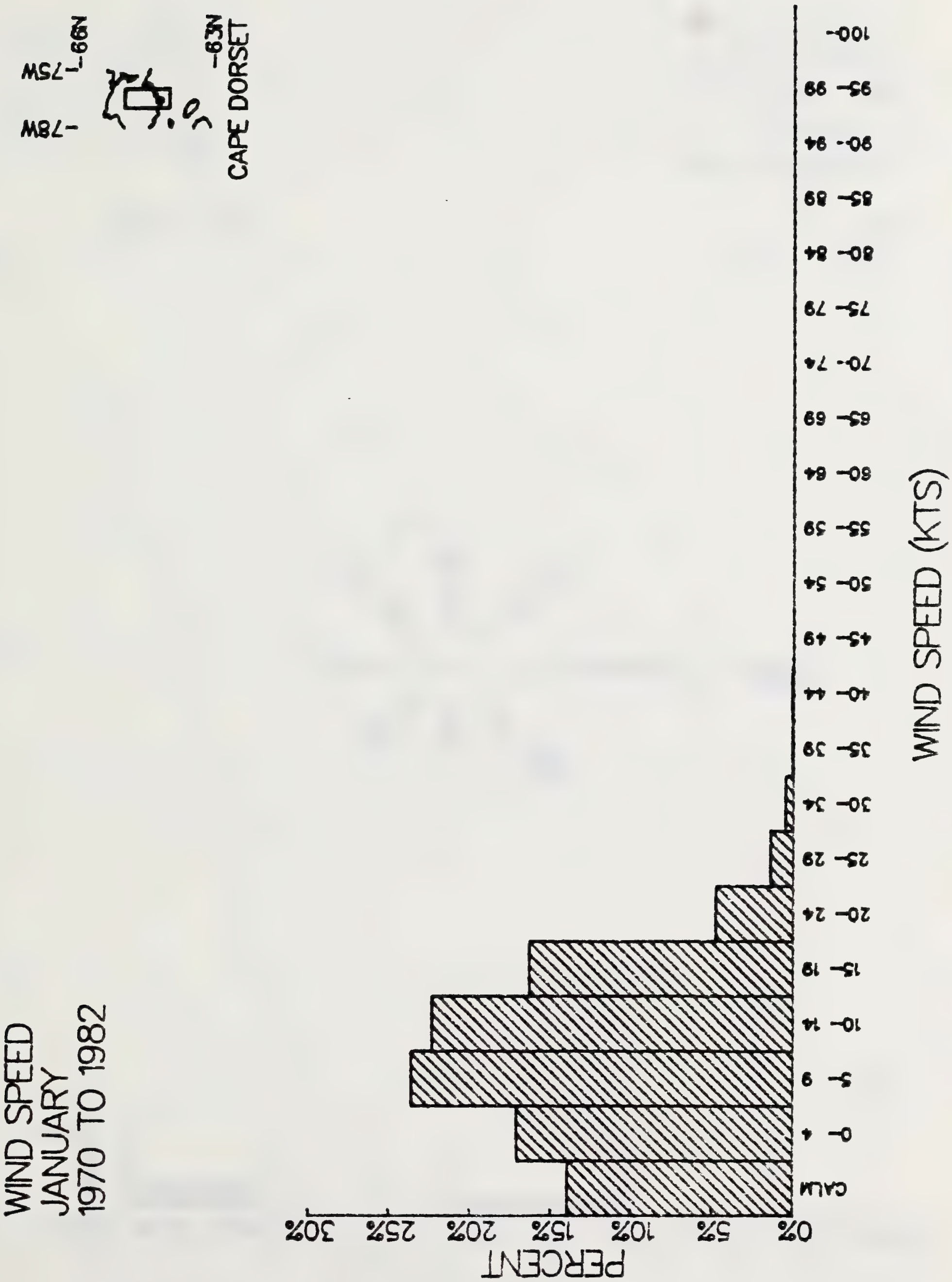
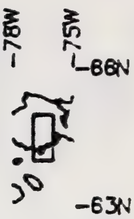


FIGURE 5

FREQUENCY OF
WIND SPEED
BY DIRECTION
JANUARY
1970 TO 1982



CAPE DORSET

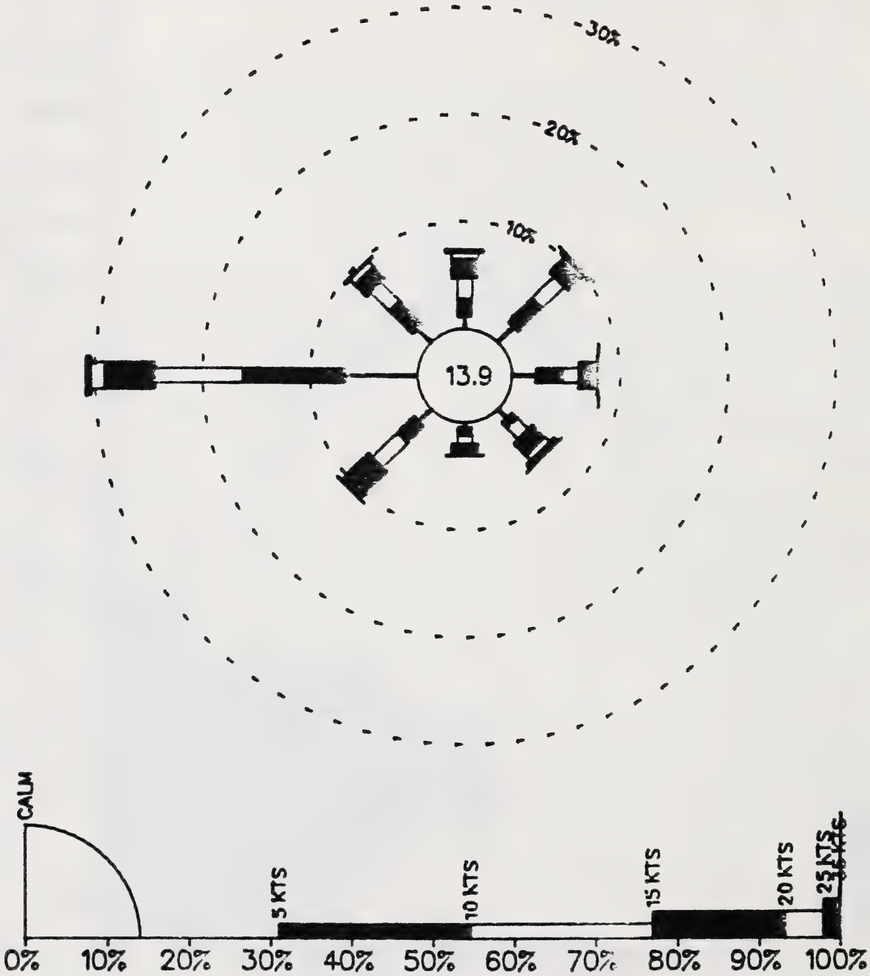


FIGURE 6

ENVIRONMENT CANADA
ATMOSPHERIC ENVIRONMENT
CANADIAN CLIMATE CENTRE

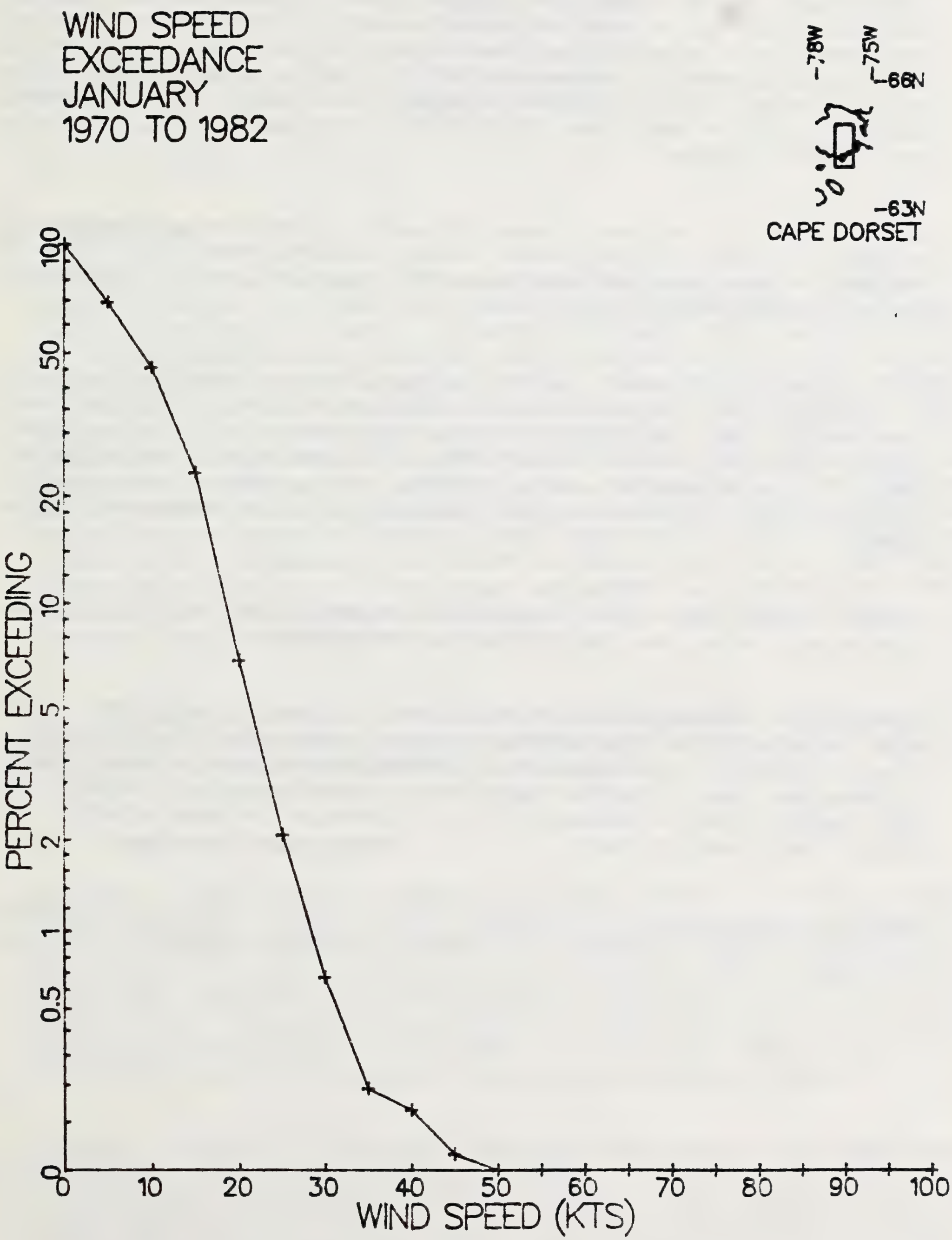


FIGURE 7

Non-Standard Data

Non-standard data is defined to mean all meteorological data collectec by a government agency other than AES, a crown corporation, an academic institution, or the private sector for research, climate studies, or for the monitoring of meteorological variables. The data could be collected either with approved AES meteorological instruments or with commercially available ones. Data could be acquired operationally on a continuous basis, for use in real time, or in a discontinuous fashion, serving a very specific purpose.

The multitude of instrument types, exposures, inspection and monitoring programs and data accuracy makes rigid standards impractical for all stations. Other agencies are encouraged to use WMO and AES guidelines for instruments and siting criteria.

Data deemed of sufficient quality, accessibility and potential use will be accepted and forwarded to the CCC for archiving. Although all non-standard data regardless of recording medium will be archived, computer compatible format is preferred. This data should be in the AES digital climatological archive format to facilitate the eventual integration of the data into the Climatological Data Management System (CDMS).

Operator agency data quality control is encouraged to maintain internal consistency, range, and temporal and spatial checks.

Lastly, full documentation of the station history is MANDATORY. This must include initial and ongoing station information (including maps, plans, photographs, and exposure), instrumentation (manufacturer, model, calibrations, etc.), station inspections, sensor moves and changes, etc. This complete station documentation will icnrease the data potential for use by a multitude of users.

Complete documentation on quality control, data formats and station information can be obtained from Western Regional Scientific Services Division.

SOIL TEMPERATURE MEASUREMENTS IN GEOTECHNICAL ENGINEERING

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Introduction

Over the past two winters, Thurber Consultants Ltd. have developed a research program for measurement of grouped temperatures at various locations throughout Alberta. Temperature records for a particular site are used to calculate air freezing index, and the freezing index and soil thermal properties are used as input for a theoretical model to predict the depth of frost penetration. The theoretical prediction is then compared with the measured frost penetration depth from in situ measurements. The data have applications in many areas of geotechnical engineering. Some of the problems under analysis are: the required depth of foundations and pipelines to present adverse frost action, the effects of insulation on depth of frost penetration, rate of thawing of frozen soils, temperature variation at depth, and control of earth construction based on soil temperature measurements. Obtaining complete, accurate, and timely temperature records for a particular area is an important part of the research program.

In this paper, examples are given of the type of soil temperature measurements being taken, and the applications of the measurements to geotechnical engineering problems are discussed.

Soil Temperature Measurements

As part of the research program into frost effects in soils, Thurber Consultants Ltd. installed a 6 m deep PVC thermistor casing in the clay soil underlying the asphalt parking area adjacent to the TCL office. The installation is located about 10 m from the north wall of the building. Snow cover throughout the winter generally consists of 10 to 50 mm of packed snow. Temperature measurements are taken by means of a moveable thermistor string placed within the PVC pipe, with temperatures being allowed to stabiize for several hours before a reading is taken.

Figures 1 through 3 illustrate temperature measurements with depth from November 24, 1982 through February 1, 1984 for the parking lot thermistor installation. Also recorded on the figures is the measured depth of frost penetration (the depth of penetration of the zero degree isotherm). The shape of the temperature versus depth curves is typical of that measured in the past at other locations.

Variation of Temperature at Depth

One important question for some geotechnical projects is the variation in temperature at a given depth. Temperature versus date throughout 1983 is plotted in Figure 4 for three selected depths in the parking lot thermistor installation. Also plotted is the mean monthly air temperature for the Edmonton Municipal Airport. The temperature at the bottom of the hole (5.94 m) varied from 10.1°C on February 7 to a low of 8.4°C on June 20, back to a high of 11.5°C in November and December. The time lag in the heat flow resulted in the lowest temperature at this depth being reached in June, and the highest temperature in December, with a maximum variation of about 3°C throughout 1983.

The temperature at 1.98 m depth varied from 2.6°C on February 7, to 1.6°C on May 11, to 13.3°C on September 27, and to 6.2°C on December 19. The lowest temperature was reached in May and the highest in September, witha maximum temperature variation of about 12°C throughout 1983.

At a depth of 0.76 m the temperature varied from -4.6°C on February 7 to 20.0°C on August 5, to -1.7°C on December 19. Because this thermistor is closer to the surface, there is little time lag between the air and soil temperature. The maximum temperature variation at this depth in 1983 ws about 25°C.

Predicted and Measured Depth of Frost Penetration

The modified Berggren equation (Sanger, 1963) was used to predict the depth of frost penetration versus air freezing index for the TCL parking lot thermistor. The method used takes into account the following soil properties: water content, unfrozen water content, dry density, thermal conductivity, latent heat, and specific heat. The air freezing index is multiplied by an empirical factor to obtain the equivalent ground freezing index.

The curve of predicted depth of frost penetration versus air freezing index is plotted in Figure 5, and is compared with the measured values for the winters of 1982-83 and 1983-84. Temperature data from Edmonton Municipal Airport was used to calculate air freezing index to December 31, 1983. For January 1984, temperature data from Valley Point subdivision near Sherwood Park was used, as the January dta from Edmonton Municipal Airport had not yet been obtained. The air freezing indices for the two locations were within 8 C° days of each other to December 31, 1983.

It can be seen from Figure 5 that the method used predicts depth of frost penetration with a fair degree of accuracy. The calculation method is somewhat simplistic, because the initial ground temperature is assumed to be constant. In fact the depth of frost penetration in a given year will depend not only on the air temperature, surface conditions, and soil

properties, but will also depend on the initial soil temperatures with depth. Ground thermal regime is briefly discussed below.

Ground Thermal Regime

The "initial" soil temperature at 6 m depth prior to the onset of freezing in 1982 was about 10.5°C in the parking lot thermistor; in 1983 this temperature was 11.5°C. This variation likely explains the slightly decreased depth of frost penetration for a given air freezing index in 1983-84 as opposed to 1982-83 (see Figure 5).

Figure 6 shows soil temperature versus depth for a second thermistor installation located near the O.S. Longman Building in south Edmonton. This installation is located in an open grassed area away from any structures. The soil temperature at 6 m depth was 6.9°C on February 1, 1984, which is 3.8°C cooler than the temperature at 6 m depth in the TCL parking lot thermistor. It appears that the proximity of the building and the asphalt parking area have resulted in a temperature increase at depth in the parking lot thermistor.

The shallower depth of frost penetration at the O.S. Longman Building location is likely primarily due to the difference in surface conditions; the area was covered by 170 mm of relatively loose snow in January of 1984.

Observations of soil temperature at a thermal power plant in southern Alberta have illustrated the effect of initial soil temperature on ground thermal regime. A thermistor string was installed in 1982 in clay fill which had been placed during the peak of the warm summer weather. The soil temperature in November of 1982 at a depth of 6 m was 14°C, which was a result of the high temperature at which the fill was placed. This temperature gradually reduced to a low of 8.0°C on July 5, 1983, increased to a peak of 9.1°C on January 5, 1984, then dropped again to 8.5°C on January 27, 1984. An in situ ground thermal regime is being gradually established in the new fill.

Similarly, if fill is placed at or near freezing temperature, the cold temperatures can affect not only the ability to compact the material, but also the rapidity with which freezing occurs. The problem of cold weather compaction of soil is discussed in the following section.

APPLICATIONS IN GEOTECHNICAL ENGINEERING

Required Depth of Foundations and Pipelines

Prediction of the depth of frost penetration is a routine requirement for geotechnical engineering projects. A frequent requirement is to specify the required depth of burial for foundations to prevent adverse frost

(frost heave and subsequent settlement) which could undermine the support of the structure. For pipelines, prevention of freezing of the pipe is also a requirement. A critical example is buried pipelines in industdrial plants which carry water for fire fighting. These lines are especially prone to freezing because they contain water at cool temperatures which frequently lies dormant for long time periods.

Thurber Consultants Ltd. have developed a computer program based on the modified Berggren equation which is routinely used to calculate the depth of frost penetration for a given set of soil parameters and thermal conditions.

One problem currently under investigation is the influence of a heated structure on soil temperatures. If heat loss from the structure occurs, this can increase the ground temperatures and reduce the risk of adverse frost effects. If the required depth of foundations can be reduced, a substantial cost saving can result for large projects.

Figure 7 illustrates the thermistor locations at a site near Hanna, Alberta which is presently being monitored. Three thermistor installations have been placed at varying distances from the structure wall. In Table 1 the depth of frost penetration in the three thermistors throughout the 1983-84 winter is given. It can be seen that heat loss from the structure has locally increased the ground temperatures close to the wall.

Effects of Insulation

Insulation is frequently used to protect foundations or pipelines from adverse frost action. A computer program based on frost penetration in a two-layer system (insulation and soil) has been developed, and is used to design the required insulation thickness and soil cover. A site in southern Alberta is currently being monitored to determine the effect of insulation on depth of frost penetration.

Thawing of Frozen Soil

Thawing of frozen soils is a problem most frequently encountered in permafrost regions, however, it is also encountered in southern climates. TCL was recently involved in a project where the soil below an ice arena had frozen to a depth of about 7 m over a period of years, resulting in frost heave and instbility of the ice surface. The ice surface was removed and the building was heated to thaw the underlying soil prior to reconstruction of the rink. A one-dimensional finite difference heat flow computer program was successfully used to predict the time required to thaw the underlying soil under the applied surface step temperature. Monitoring of the ground temperatures with thermistdors was used to confirm the results of the theoretical calculation as thawing progressed.

Temperature Variation at Depth

The prediction of temperature variation at a given depth is one problem which can arise in geotechnical engineering. In a power plant in southern Alberta, a series of buried tie rods was to be used as part of a foundation system. The designers required TCL to provide the probable maximum temperature variation at the various tie rod depths so that the expansion/contraction of the rods and consequent induced stresses could be predicted. A theoretical prediction was made, and soil temperature monitoring data were used to confirm that the prediction was logical.

Control of Earth Construction

One aspect of geotechnical engineering is quality control of the placement of earth fill for embankments, dams, and other structural fills. Laboratory testing has demonstrated that once the soil is more than a few degrees below freezing temperature, an adequate degree of compaction cannot be obtained. Portable thermistor probes are frequently used in constdruction control in late fall/early witner to determine whether the soil temperature is adequate to obtain the required soil density. The soil temperature measurements help ensure that inadequate fill is not placed, and also allow construction to proceed as long as possible, resulting in economic advantage to the owner and/or contractor.

Use of Climate Data

Some of the uses of climate data in geotechnical engineering are as follows:

1. Air freezing and thawing indices can be determined for various areas. This information can be used to predict depth of frost or thaw penetration.

2. Air temperature data can be used to test the validity of theoretical models for heat flow in soils by comparing observations with predictions.

3. Climatic conditions can influence the progress of major earth construction projects. Temperature and precipitation records can be used to resolve conflicts between owners and contractors.

In urban areas such as Calgary or Edmonton, accurate and complete climate data can usually be obtained within a reasonable time period. However, in rural areas, where the greatest number of large earth construction projects are located (earth dams, mines, thermal power projects), climate records from local weather stations are often incomplete and cannot be obtained quickly. On some of the more recent projects, the owner has set up a weather station on the job site at the start of the project, however, this is still not general practice. Improvement in the system of climate data collection and processing would be of great advantage for

geotechnical engineering projects.

Reference

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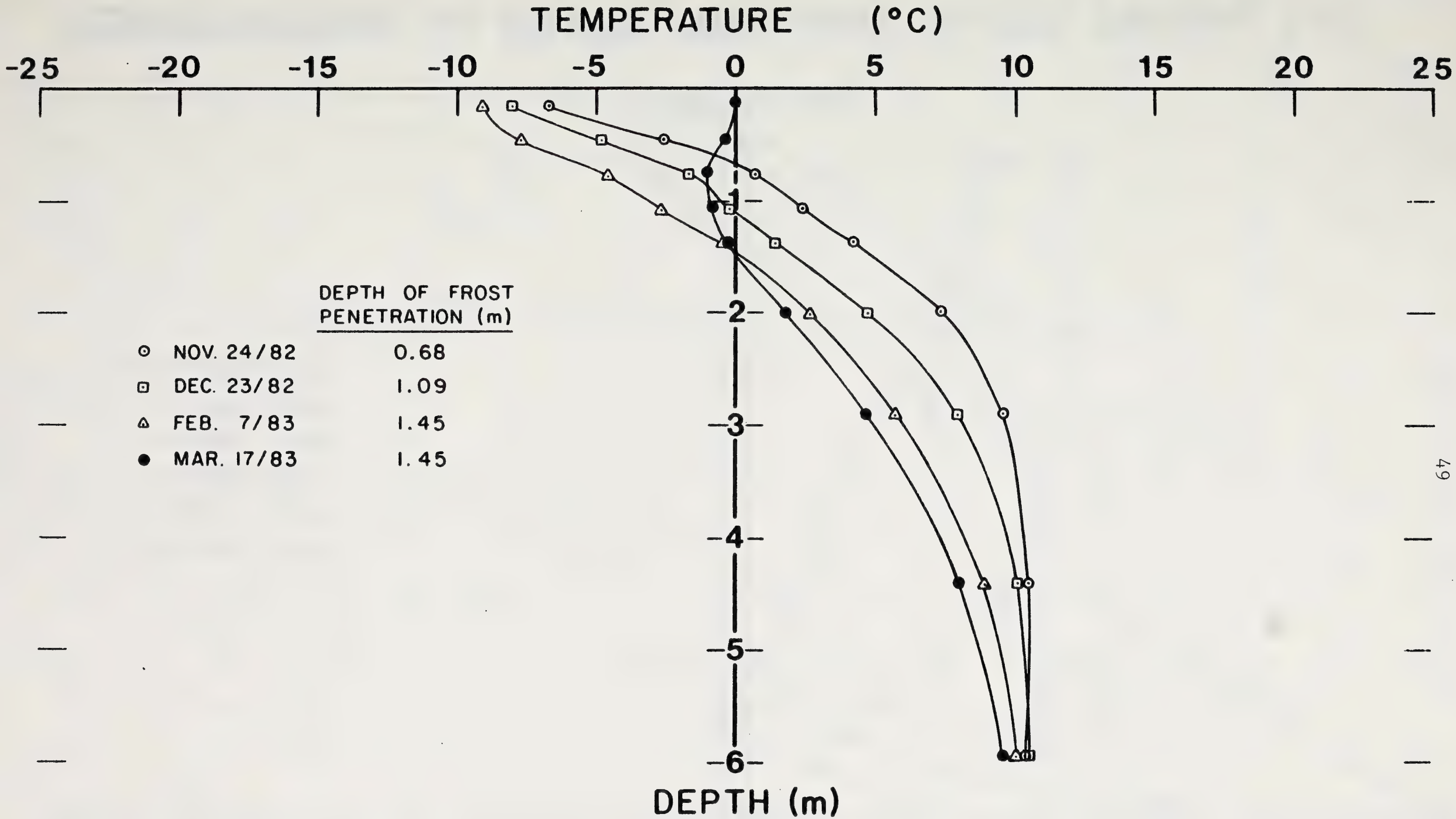
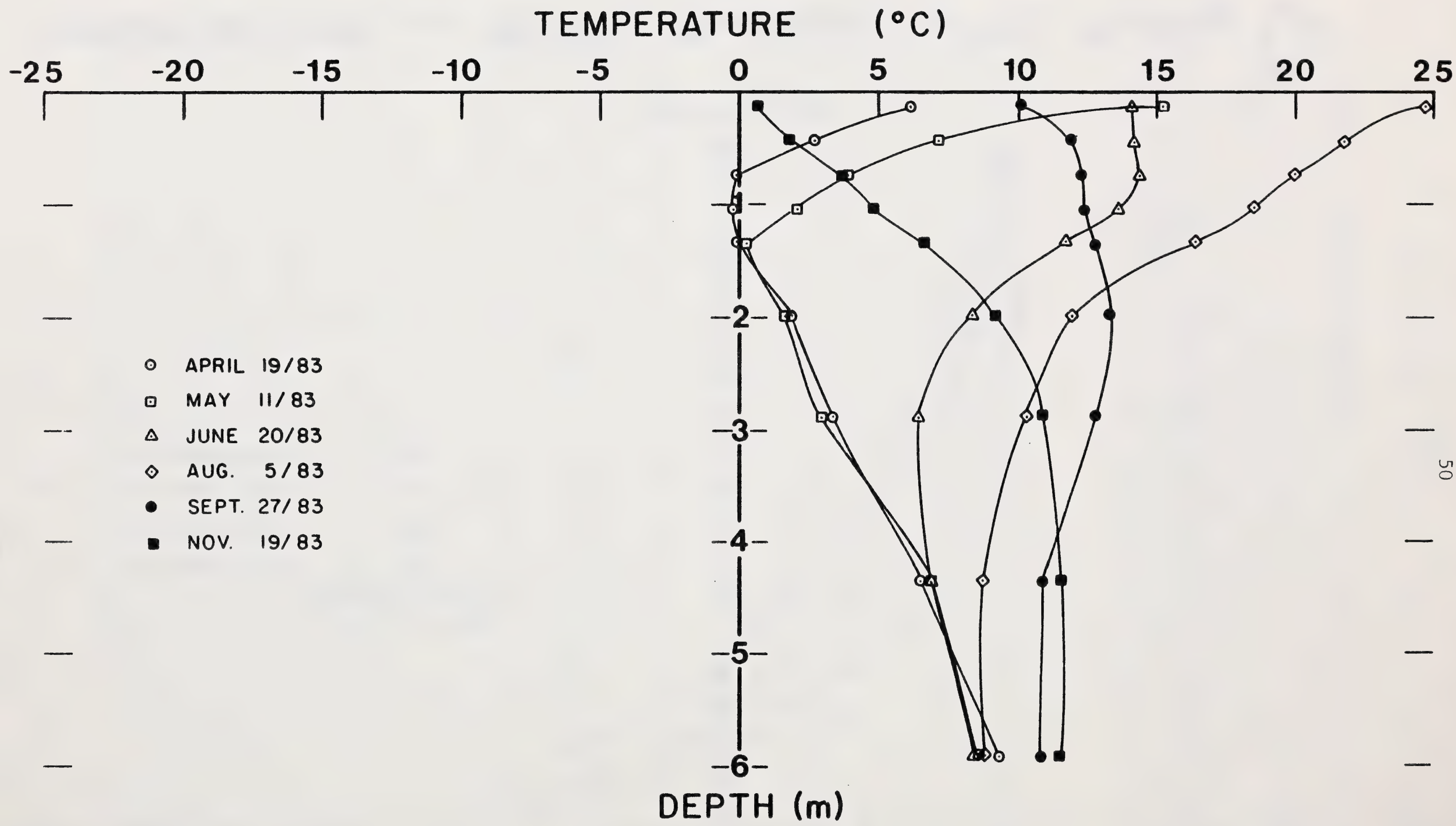


TEMPERATURE vs. DEPTH, Thermistor in TCL Parking Lot

WINTER 1982–83

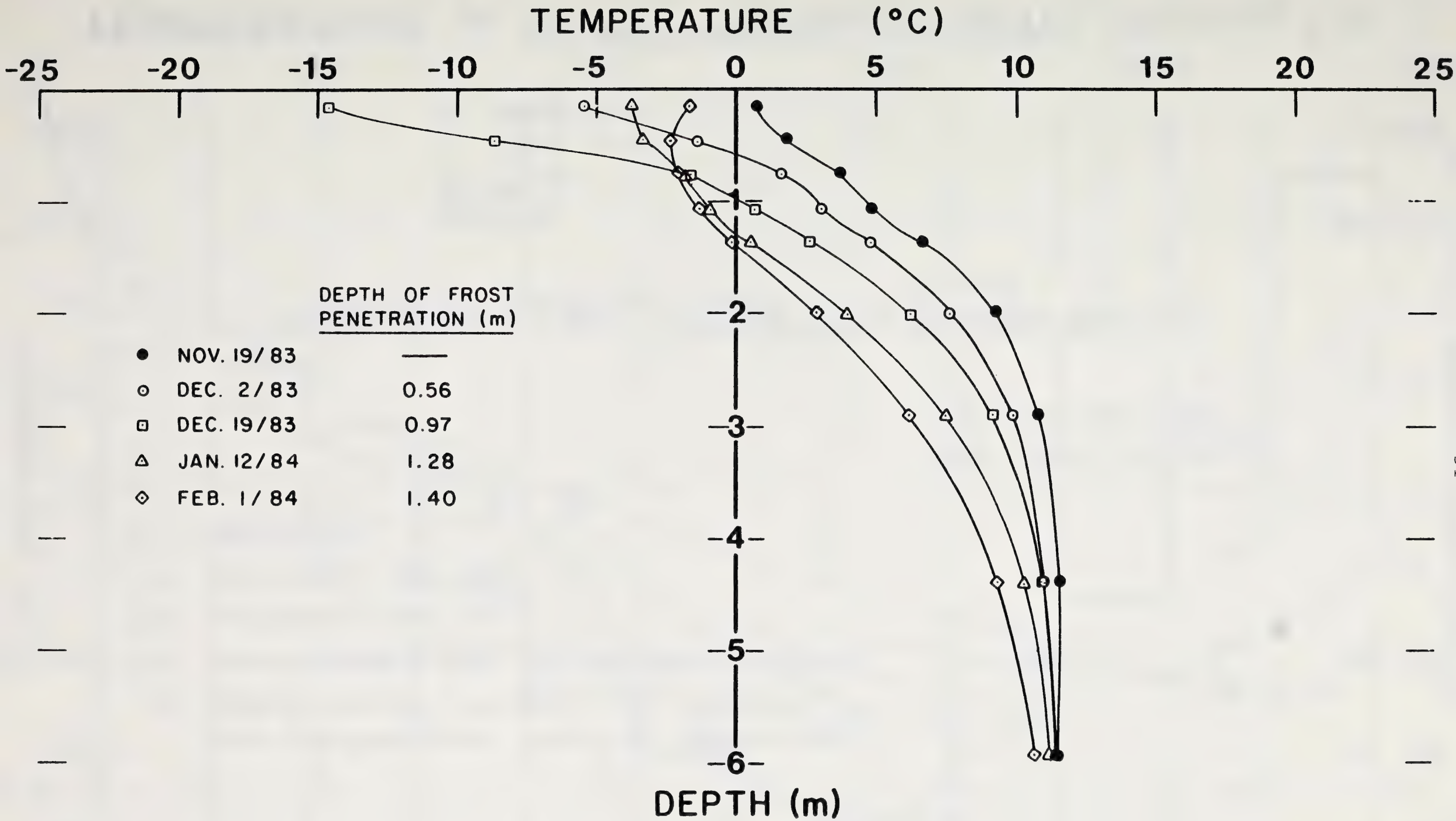
FIGURE 1



TEMPERATURE vs. DEPTH, Thermistor in TCL Parking Lot

SUMMER 1983

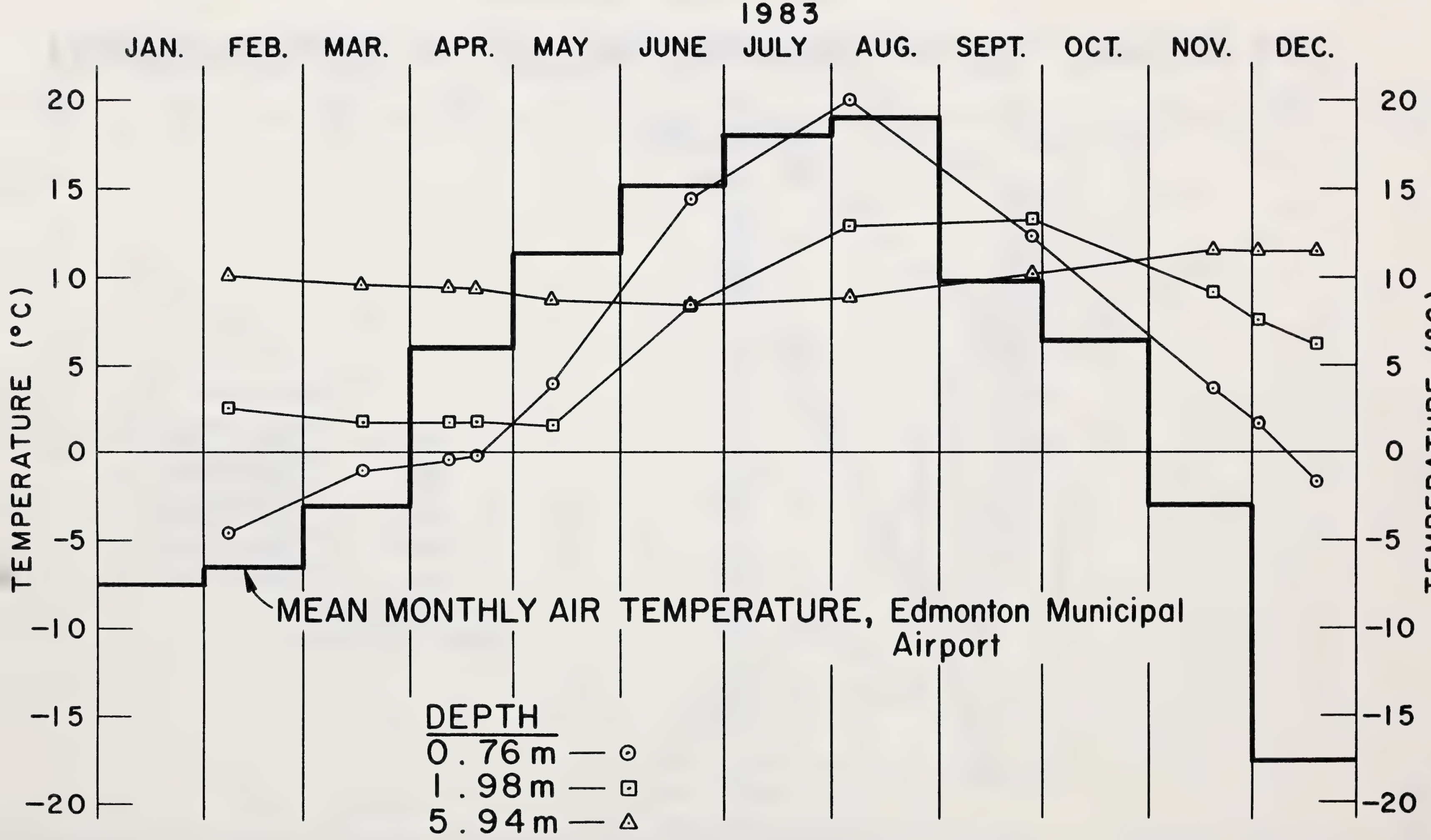
FIGURE 2



TEMPERATURE vs. DEPTH, Thermistor in TCL Parking Lot

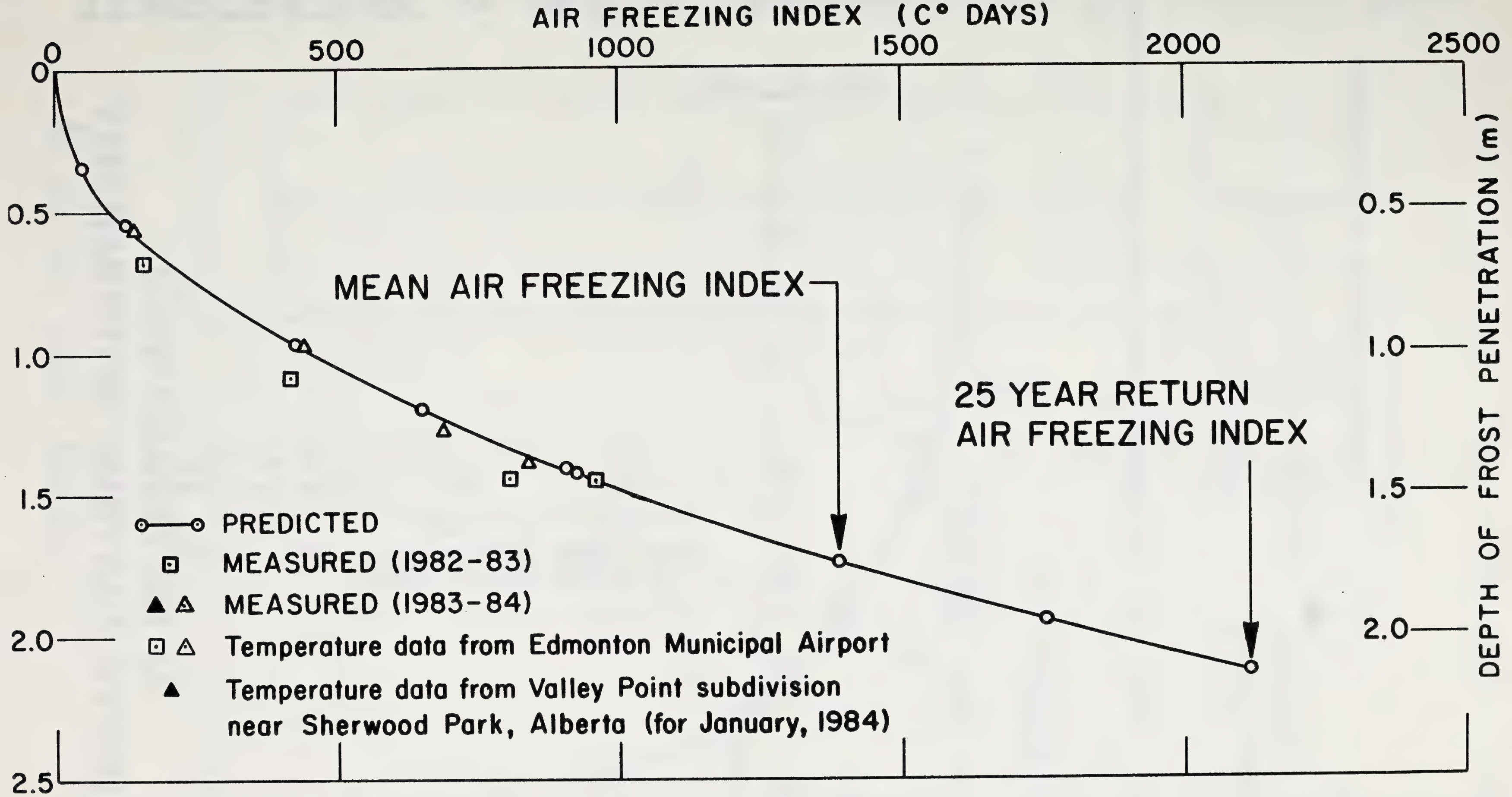
WINTER 1983 — 84

FIGURE 3



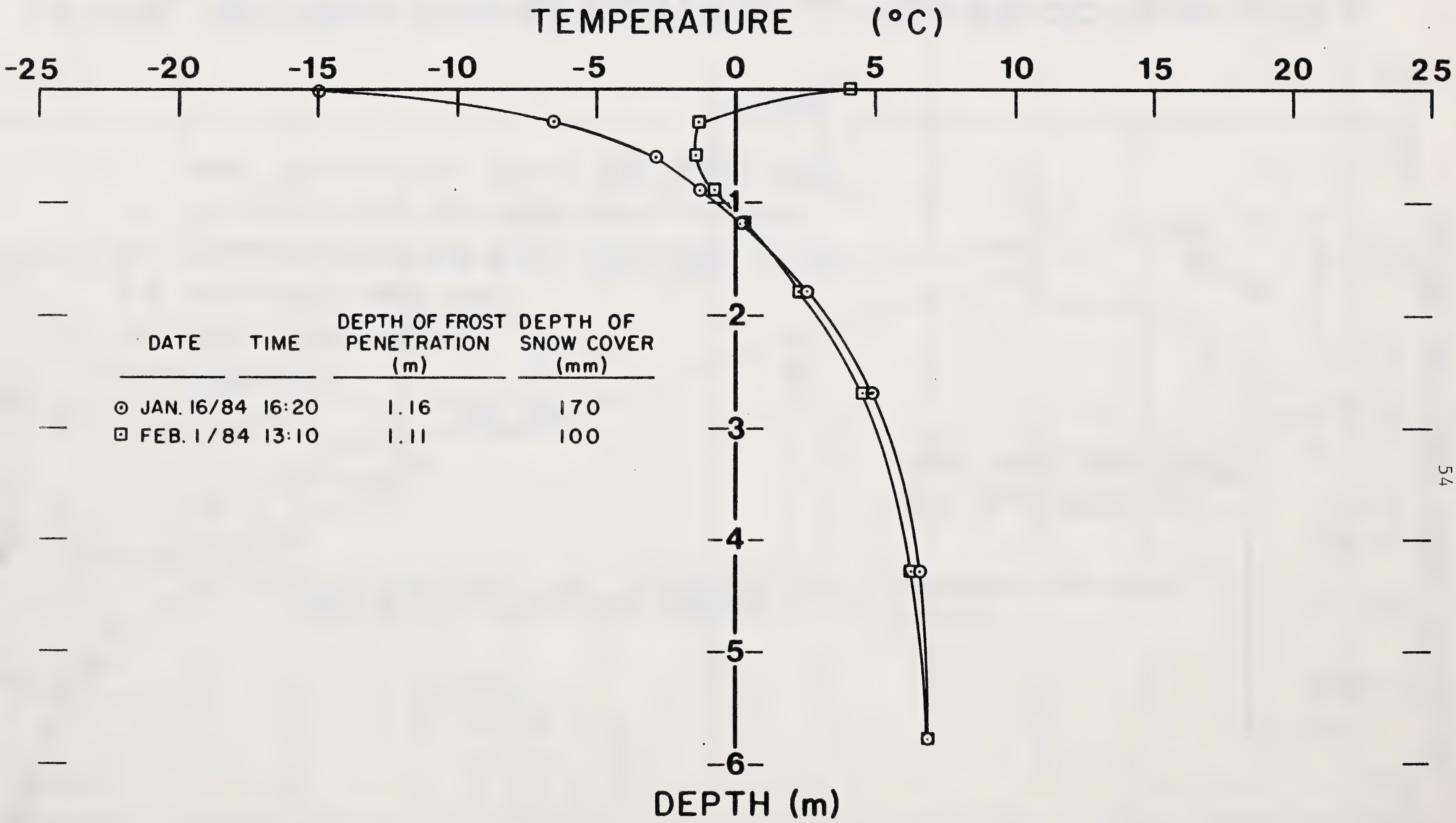
TEMPERATURE vs. DATE, Thermistor in TCL Parking Lot

FIGURE 4



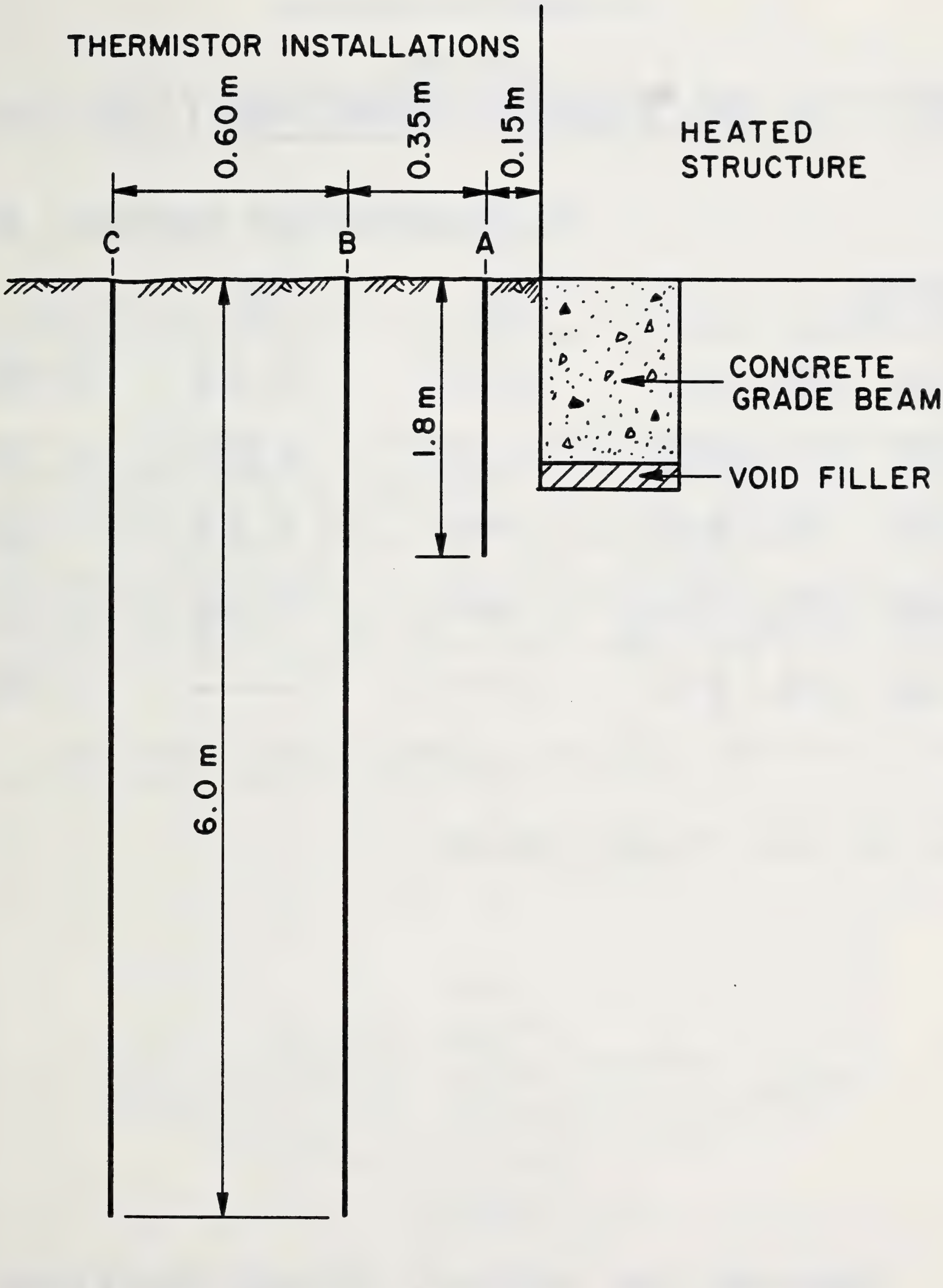
DEPTH OF FROST PENETRATION vs. AIR FREEZING INDEX, Thermistor in TCL Parking Lot

FIGURE 5



TEMPERATURE vs. DEPTH, Thermistor near O.S. Longman Bldg.

FIGURE 6



CONFIGURATION OF THERMISTOR INSTALLATIONS

(for site near Hanna, Alberta)

FIGURE 7

TABLE I

DEPTH OF FROST PENETRATION (m)

DATE	THERMISTOR INSTALLATIO A	B	C
NOV. 25/83	0.26	0.42	0.80
DEC. 21/83	1.03	1.05	1.32
JAN. 5/84	—	1.27	1.60
JAN. 27/84	—	1.16	1.68
FEB. 14/84	—	—	1.50

(for site near Hanna, Alberta)

DEPTH OF FROST PENETRATION

MAPPING METHODS IN CLIMATOLOGY

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INTRODUCTION

Climatic maps can be most useful in displaying information and in some cases be most misleading to the uninitiated user. This review of current methods will document possible errors in mapping climate and identify limitations for the user.

The climate of an area can be implied on a very broad scale by its vegetation assuming genetic homogeneties or it can be defined by parameters that can be measured to provide an improved level of detail. For the purpose of this paper, climate maps are to be interpreted as a series of single parameter maps. The choice of parameters and the monitoring network design are dependent on the ultimate use of the climatic information. For aviation; cloud heights, visibilities, wind speed and direction are of importance, for recreation and wildlife; snow depth could be chosen. A particularly good discussion for agriculture use can be found in WMO's technical note number 133 (1).

To obtain overall climate, a number of maps can be combined by overlay, factorial/cluster analysis or other methods (Fig. 1).

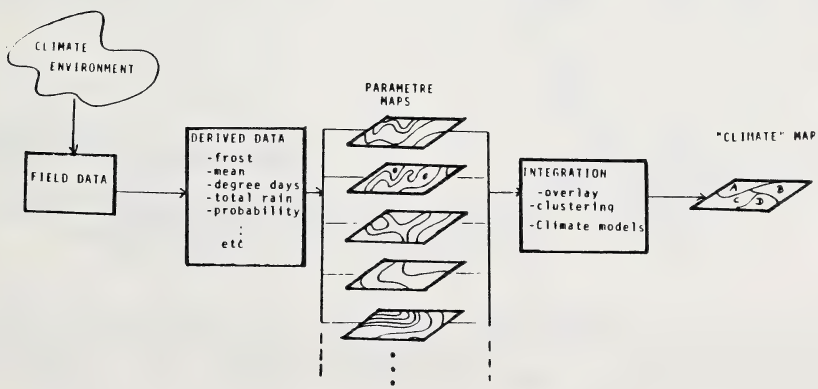

Figure 1. General Procedure for Mapping Climate

PRELIMINARY ANALYSIS

Any climate map is only as good as the data input. An initial analysis must consider the quality of the data, its variation in space and time and its relationship with other variable (2). In particular it is important to establish if any differences between stations exist. If none exist, then no significant lines can be drawn. A Duncan multiple range test (3) will indicate if there are any differences to be mapped. A recent test for a mesoclimatic network over a 4 year period in northern Alberta showed that growing degree days could be mapped, but not rainfall (Fig. 2).

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	STATION
A	1388.3	4	3073735
B A	1370.0	4	101121
B A	1364.3	4	3072720
B A	1338.5	4	101272
B A C	1327.0	4	101202
B A C	1326.8	4	101251
B D A C	1303.8	4	101262
B D A C	1293.3	4	101051
E B D A C	1280.3	4	101061
E B D A C F	1269.5	4	101232
E B D A G C F	1256.3	4	101322
E B D H A G C F	1220.0	4	101142
E B D H A G C F	1219.5	4	101311
E B D H A G C F	1212.3	4	101351
E B D H A G C F	1211.0	4	101242
E B I D H A G C F	1200.5	4	101161
E B I D H A G C F	1199.8	4	101192
E B I D H A G C F	1195.0	4	3073146
E B I D H A G C F	1187.8	4	101282
E B I D H A G C F	1175.8	4	101031
E B I D H A G C F	1167.0	4	101012
E B I D H G C F	1164.8	4	101414
E B I D H G C F	1163.8	4	101044
E B I D H G C F	1160.8	4	101212
E I D H G C F	1114.5	4	101451
E I D H G C F	1110.5	4	101341
E I D H G F	1097.8	4	101431
E I D H G F	1092.3	4	101441
E I H G F	1059.3	4	101022
I H G F	1049.5	4	101382

May-September Growing Degree Days

ANALYSIS OF VARIANCE PROCEDURE
DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE RAIN

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.
ALPHA LEVEL=.01 DF=75 MS=1839.83

GROUPING	MEAN	N	STATION
A	145.000000	4	101012
A	138.500000	4	101441
A	133.750000	4	101061
A	125.250000	4	101083
A	125.000000	4	101121
A	124.250000	4	101031
A	117.500000	4	101414
A	116.250000	4	101223
A	114.750000	4	101044
A	114.000000	4	101251
A	113.000000	4	101184
A	111.000000	4	101161
A	110.000000	4	101142
A	110.000000	4	101282
A	109.750000	4	101333
A	109.500000	4	101431
A	107.500000	4	101423
A	102.750000	4	101232
A	102.750000	4	101403
A	102.000000	4	101262
A	100.750000	4	101173
A	100.000000	4	101192
A	99.750000	4	101311

May-September Rainfall (mm)

Figure 2. Duncan Multiple Range Test Output From Statistical Analysis System (4)

The line spacing on "meaningful" maps (i.e. 95% confidence) is at least two standard deviations. An even greater spacing may be required due to interpolation methods. Maps showing less spacing are appealing, but may also be misleading.

CONTOURING OF VALUES

Three distinctive methods have been identified: objective analysis, modelling and remote sensing.

1. Objective Analysis

This method is well suited for computer mapping and some excellent software has been developed. Three techniques for contouring the data are examined: linear interpolation, polynominal fitting and weighted means.

1.1 Linear Interplolation

Lines are drawn between stations directly. For example, a line of 100 units would be drawn halfway between a station reporting 90 units and another reporting 110. No physics are included. In this example, the line may in reality fall closer to the 90 unit station due to topographic or other effects. Also, the accuracy of the lines decrease with distance from stations.

Linear interpolation can be computerized by a technique of triangulation (5). Locations are joined by straight lines and segmented by linear interpolation (Fig. 3). Smoothing these segments produces the final results.

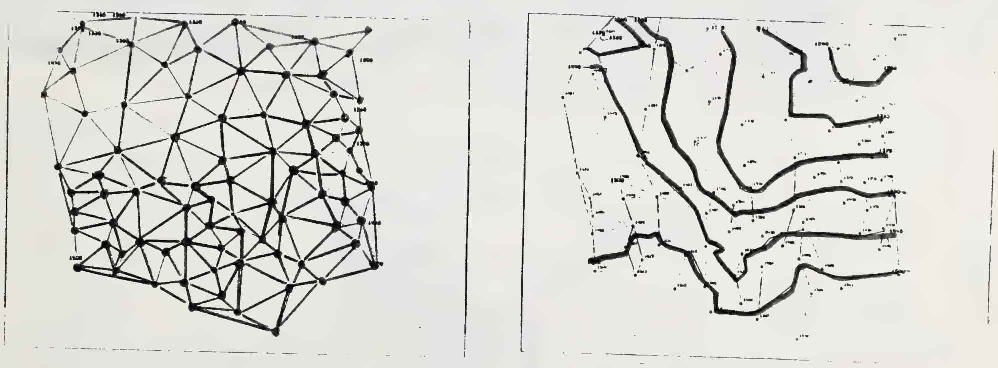

Figure 3. Triangulation Procedures

Linear interpolation is useable for large scale mapping, provided the limitations are understood. A couple of examples have been reproduced to show these limitations (Fig. 4). These types of maps can be duplicated from software that is readily available from a number of sources (6, 7).

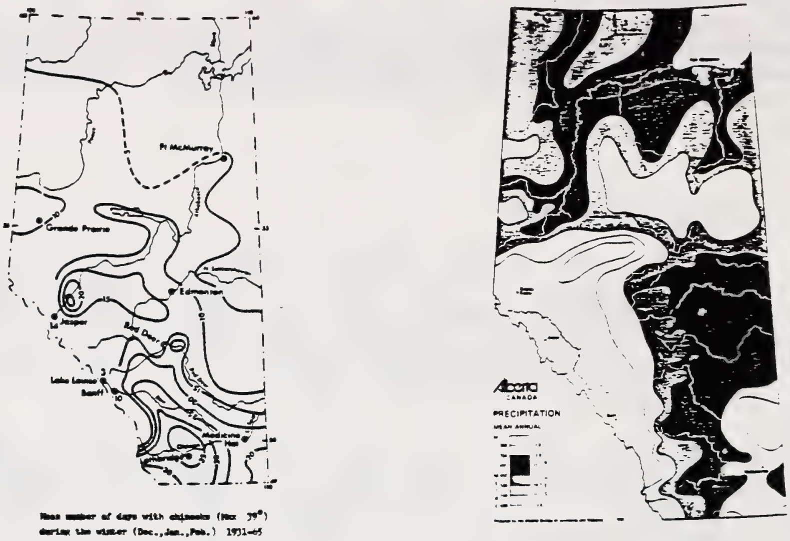

Figure 4. Examples of Linear Interpolation Maps

1.2 Polynominal (or Trend Surface) Fitting

A number of algorithms have been written to fit polynominal surfaces to irregularly spaced data (8). Interpolation from these surfaces is generally more realistic than linear interpolation in that gradients are conserved (Fig. 5). Outputs are generated in grid point form or irregular x-y coordinate basis.

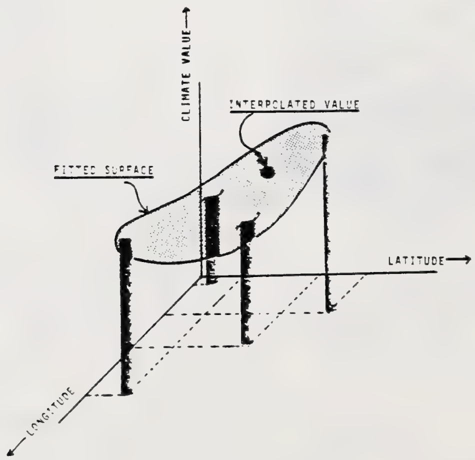

Figure 5. Polynominal Surface Fitting

This technique has a number of problems. There are no physical controls on the placing of lines (i.e. topography, etc.) and sometimes the interpolation leads to ridiculous results, such as negative rainfall (Fig. 6). In practice, however, computer programs have "band-aids" that limit such values on output. This technique is also very much dependent on station spacing for its accuracy.

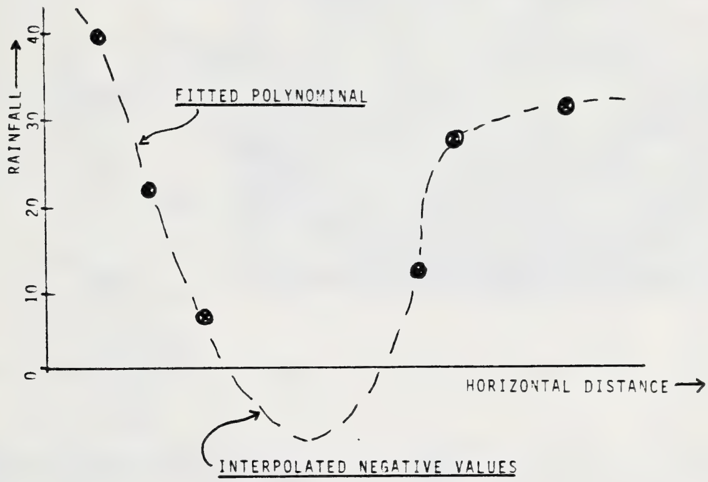

Figure 6. Polynominal Interpolation Error

1.3 Weighted Interpolation

One of the better known meteorological techniques is that of Cressman's algorithm (9). It is still used in one variation oor another in numerical weather analysis, and is implicit in many contouring packages. Irregularly spaced station data are fitted to a regular grid using a scanning radius and weight which are proportional to grid point - station distance (Fig. 7).

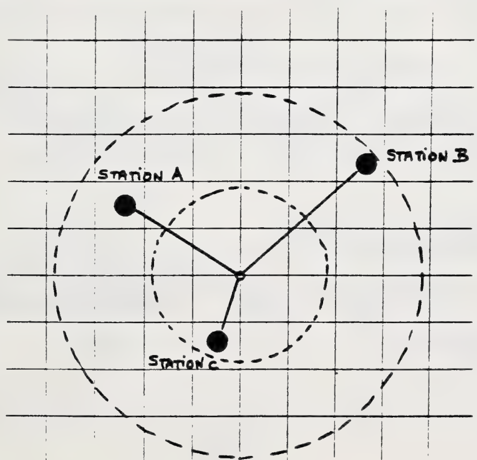

Figure 7. Weighted Interpolation

Common problems include the choice of grid spacing, scanning radius and smoothing parameters, all of which are determined experimentally. Grid spacing, in particular, is a trade-off with irregular station density. Physiographic influences are again ignored. In fact, unless "band-aids" are used, it is also possible to generate grid points with negative rainfall! A sample map using this technique has been reproduced in Figure 8.

Figure 8. Weighted Interpolation Map

2. Modelling

Physiographic criteria have been used to aid in interpolating values for various climatic parameters in locations where no specific climatic data is available. Findlay (10, 11) described several interpolation techniques while Hopkins (12) and Shawinigan Engineering (13) developed equations to interpolate monthly means from elevation, latitude, etc. Estimated monthly means are sometimes further processed to calculate values of frost-free period, degree days, etc. (14, 15). It is also possible to model these derived statistics directly, which avoids additional errors resulting from conversion of monthly means.

Modelling can introduce the physics that is lacking in objective analysis but in general will smooth out detail near stations due to regression errors. These errors increase the spacing required between significant isolines. Added model errors are described in detail in statistical texts (16).

2.1 Simple Regression Model

The most common model has been the use of climate as a function of elevation and the transfer of that equation to a topographic map base (Fig. 9).

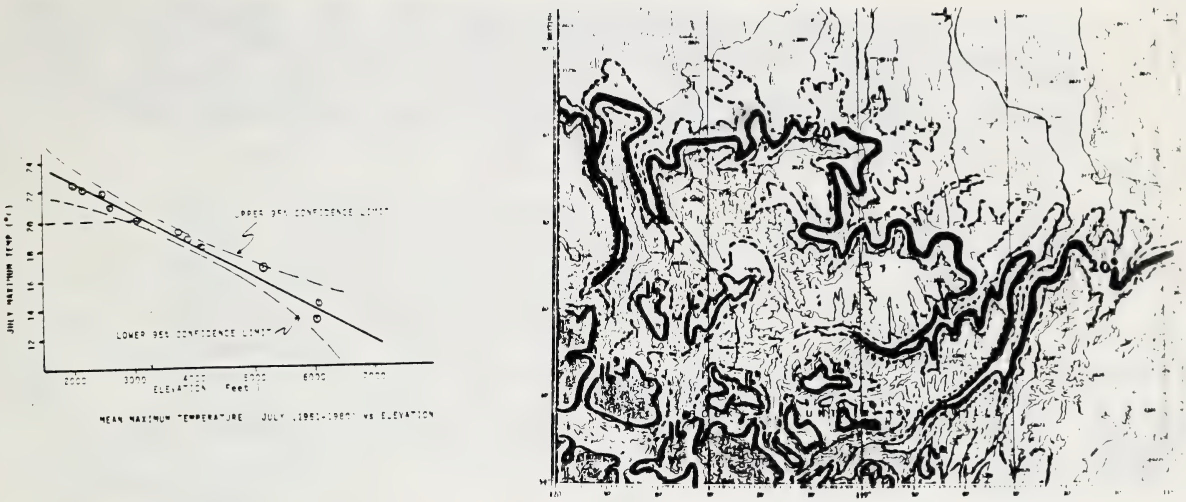

Figure 9. Mapping from a Simple Elevation Model

Most of the single element models are simplifications of complex controls on climate. For example, models of precipitation vs elevation are sometimes misused, as substitute for slope and aspect models (2).

2.2 Multiple Regression Models

More complex physics can include such climatic controls as latitude, slope, aspect, curvature. In general, these controls are a function of the mapping scale (Table 1). For example, latitude is useful in mapping large areas but not particularly helpful in mapping small areas. An analysis of variance (ANOVA) can be used to determine the relative significance of the variables used.

MACROCLIMATE (100 km)	MEOSCLIMATE (10 km)	MICROCLIMATE (1 km)
Latitude Elevation Distance from: - oceans - mountains - barriers - etc.	Slope/Aspect: Shading Surface Shape % and Type of Vegetation Cover Albedo Distance from: - valleys - hills - lakes - etc.	Soil Surface - texture - moisture - heat response Local cold air barriers (bushes, tree clearings) Surface cover, age of growth

Table 1

Sample Modelling Variables

Two examples are presented; one province wide, the other in a small 100 x 200 km area in northern Alberta using a special mesoclimatic network. The province wide model (Fig. 10) shows that growing degree days were well related (r^2 = 0.78) to elevation and latitude. Longitude was not a significant factor (prob > T =. .838).

DEP VARIABLE: GDD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	3	7720878	2573626	247.444	0.0001
ERROR	207	2152974	10400.840		
C TOTAL	210	9873851			

ROOT MSE	101.985	R-SQUARE	0.7820
DEP MEAN	1178.462	ADJ R-SQ	0.7768
C.V.	8.654038		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > ITI
INTERCEP	1	5980.763	318.379	18.785	0.0001
ELEV	1	-0.212184	0.010389	-20.426	0.0001
LAT	1	-79.936526	4.254563	-18.788	0.0001
LONG	1	0.732903	3.593282	0.204	0.8386

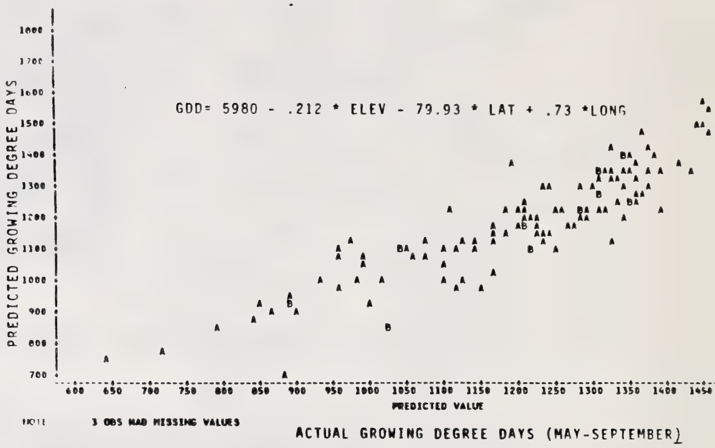

Figure 10. Province Wide Model of Growing Degree Days

A smaller scale model (Fig. 11) needed the "refinements" of vegetation cover (% forest, 1 km grid) and curvature (Laplacian, 9 points, 1 km grid) to model the effects of valleys and possible cold air barriers in the forest (17).

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: GDD

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE
MODEL	3	211614.67919730	70538.22639910	20.12	0.0001	0.707115
ERROR	25	87650.07942339	3506.00317694		ROOT MSE	
CORRECTED TOTAL	28	299264.75862069			59.21151220	

SOURCE	DF	TYPE I SS	F VALUE	PR > F
ELEV	1	115738.11777291	33.01	0.0001
LAP	1	23469.85260530	6.69	0.0159
FOREST	1	72406.70881910	20.65	0.0001

Figure 11. Small Scale Model of Growing Degree Days

Variables must also have physical meaning: the use of distance from mountain barriers may be more appropriate than longitude in Hopkins model (11) for example. A point that is also often overlooked in multiple regression models is the predictive range of models. Any model derived from stations having 0-2% slope could not be used to predict for locations of 10-30% slope.

Models can also be inadequate when important climatological controls are excluded or when these controls have multicollinearity (18). Climatologists are encouraged to review the adequacy and validity of their models with statisticians or biometricians. The main disadvantage of multiple regression models is in the implementation. The data input requirements can be enormous. A 1 km grid of elevation, another of vegetation etc., can be time consuming to digitize and input. Results are, however, repeatable as compared to manually hand drawn analysis.

3. Remote Sensing

Remote sensing by mobile ground surveys and airborne or satellite imagery offers excellent areal coverage at the expense of quantitative and historical coverage. The mapping of temperatures is promising, particularly in the delineation of frost patterns on clear nights (19, 20). Rainfall mapping is more complex, but to some extent can already by done with RADAR or satellite imagery.

The major difficulty in using remote sensing for climate mapping is in the integration of the data over time. Since most remote sensing applications are designed for real-time use, other analyses must also be available to provide a good historical coverage.

A recent application of remote sensing used phenological data (i.e. "trees turning red", etc.) to assess the representativeness of climate sites (21). Vegetation response to climate is complex and needs to be better understood before a wider application of this technique can be used.

CONCLUSION

Mapping climate, especially for mesoscale application needs to combine the advantages of all methods described. Objective analysis tend to be more accurate near stations than modelling, since modelling "smooths out" the data due to imperfect regression equations. On the other hand, modelling gives the best estimate where no specific climate data exists, which is precisely where objective analyses fail. To facilitate the generation of maps, the use of grid points appears to be the best method of incorporating objective analyses with multiple regression models. Each gridded parameter map can then be adjusted with remote sensing or other data. The final integration into one "climatic" map (Fig. 1) could use these grid points for overlay, cluster analysis or crop-weather model for specific application.

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WEATHER EXTREMES IN ALBERTA: 1880 TO 1960

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1. Introduction

In the past twenty years, especially following Canada's centennial year, new Alberta community histories have appeared in large numbers each year resulting in coverage of most settled districts in the province. Almost all of these books include individual family recollections which, in turn, often include valuable historical records of the impact of weather and climate on life, property, and activities on all scales from farms and hamlets up to regions. Remembered events include hail, summer frosts, blizzards, dry years, floods, ice storms, severe winters, dust storms, chinooks, tornadoes, and other local weather peculiarities which attracted attention because of rarity, beauty, or drama. The written records complement and supplement the numerical statistics from sparsely-distributed conventional weather stations.

The purpose of this study is to identify those past weather extremes which were most frequently mentioned by rural residents of Alberta, and to attempt to relate this particular measure of the impact of weather extremes to conventional climatic data. The work is incomplete and this report is best described as an interim progress report.

2. Data Coverage

The basic data were derived from 142 community histories representing about 40 percent of the surveyed area south of township 61 in Alberta. On average each history covers about 6 townships. The largest gaps in spatial coverage occured in Improvement District 1, centered near Medicine Hat, and Improvement District 14, which includes the Edson and Hinton distdricts. All weather events identified by specific years were logged. Some errors in dates are to be expected for local events of small impact. However, such errors can be dealt with statistically in large samples. The fact that attempts were made to associate specific dates with specific events adds conviction to the significance of those events.

In preparing frequency distributions each event was counted only once per history book even though it may have been noted by many residents. Therefore, high frequencies resulted either from large impact areas from a single event or from frequent similar small-scale events in the same year within central and southern Alberta. The frequency distribution are believed to be most representative of the period from 1910, when

massive rural settlement began, to the mid 1960s when significant numbers of the histories were published.

3. Results

3.1 Severe Winters

The frequency distribution of reports of severe winters is shown in Figure 1. It is clear from this figure that the winters of 1906-07 and 1919-20 were outstanding for their severity. These, together with the winter of 1935-36, were mentioned most frequently in central Alberta, while the winter of 1886-87 was mentioned only in southwestern Alberta. The absence of date scattering in the neighbourhood of 1907 and 1920 is quite remarkable and demonstrates that these were events of major impact.

Mean winter temperatures (December, January, and February) at Edmonton are show in Figure 2 for comparison with Figure 1. Edmonton was selected as representative of central Alberta. However, the results are insensitive to this choice because mean winter temperatures at Edmonton are stdrongly correlated ($r>0.9$) with those at other weather stations with long-term records such as Medicine Hat and Calgary. Evidently mean winter temperature data show little correspondence with severe winters as shown in Figure 1. The winters of 1886-87 and 1935-36 were cold but not appreciably colder than those of 1949-50 and 1968-69. Furthermore, the winters of 1906-07 and 1919-20 were not identified as unusual by mid-winter temperature data.

Many written descriptions of these severe winters are available in the local histories and it can be deduced from these that they were characterized by great length and by deep persistent snow cover. It is reasonable to assume that these characteristics had a greater impact on rural residents than extreme mid-winter temperatures. For both winters (1906-07 and 1919-20) there were many reports of winter snowbanks that persisted until early July. For 1907 there were two reports of remnants of sheltered winter snowbanks that persisted until the following witner - observations that seem incredible in the light of our experience in recent winters in central Alberta.

On the basis of these descriptions a "severe winter" index was devised by assigning equal weights to early snowfall amount (October and November), low mean temperatures from October to March, heavy total snowfall, and low spring temperatures (April and May). The dimensionless annual severe winter index W ($-1 \leq W \leq 1$) shown in Figure 3 was computed from:

$$W = \frac{1}{4} \sum_{i=1}^{4} \frac{x_i - \bar{x}_i}{R_i} \qquad (1)$$

Where: x_1 = total snowfall (September to May)
x_2 = early snowfall (October and November)
x_3 = mean temperature (October to March)
x_4 = mean temperature (April and May)

and where $\bar{x}_i$ and R_i represent the mean value and range, respectively for each variable for the period of record at Edmonton (1883-1983). Ranges were computed separately for positive and negative deviations from the means and appropriate sign adjustments were made so that large positive values of W were favoured by low temperatures and heavy snowfall. The variables x_2 and x_4 serve to identify early and late winters, respectively, in central Alberta. There is no assurance that the same indicators are valid for southern Albertan.

The frequency distribution of W shown in Figure 3 corresponds much more closely with the community history reports of Figure 1 in that the 3 worst winters identified by rural residents were identified also, in correct order, by the combination W of measured temperature and snowfall data at Edmonton. Further refinement of a severe winter index is possible but does not appear to be justified at this time by the limited information in Figure 1.

3.2 Dry Years

Dated reports of outstanding dry years, wet years, and dust storms are shown in Figure 4. With notable exceptions in 1910 and 1914 wet and dry years occurred in groups perhaps more appropriately identified as wet and dry spells. Dust storms were reported first in 1918 and by increasing frequencies appeared to show evidence of the cumulative effect of the dry spells of 1917-26 and 1929-1938.

Monthly precipitation, unlike monthly mean temperature, is not well correlated over large distances in Alberta. For that reason, and because almost all reports of dry years came from the community histories of southern Alberta, precipitation data from Medicine Hat and Calgary were combined for comparison with dry and wet year reports. The results for the period March to July in each year are shown in Figure 5. Here, as in the comparison of severe winter reports with winter temperatures, the correspondence between community history reports and climatic data is poor. In particular, the order of selection of the most important dry years differed in Figures 4 and 5. Furthermore, spring and early summer precipitation showed much less tendency for dry spells or groupings of dry years than Figure 4.

Descriptive comments in the community histories suggest that the dry years shown in Figure 4 were identified primarily on the basis of their impact on the crops and water supplies of individual farms. In an attempt to develop a "drought" index from measured temperature and

precipitation data, it is instructive to consider the results of previous studies of the relationships betwen weather factors and crop yield even though crop yield depends on many other variables such as soils, pests, diseases, and farming practices. The key parameter from the point of view of weather factors is soil moisture which rises and falls in response to precipitation, precolation, runoff, and evapotranspiration. The only available long-term measurements are those of screen air temperatures and gauge precipitation which are poor surrogates for soil moisture. Nevertheless, crop yield studies have shown significant correlations with spring and fall precipitation for selected crop sequences (hopkins, 1936). Winter snowfall (November to March) on frozen ground did not contribute significantly to crop yield variations at Swift Current according to Barnes and Hopkins (1930). When fall precipitation is added to that of the following spring and summer, the results failt oa ccount for the ranking of dry years shown in Figure 4. All that remains to be tested with available data are the effects of temperature (Williams, 1962) and the cumulative influences of prior years.

A dimensionless drought index D ($-1 \leq D \leq 1$) was defined by

$$D = \frac{\sum_{i=0}^{n} a^i I_i}{\sum_{i=0}^{n} a^i} \qquad (2)$$

where I_0 is the drought index for the current year and I_1, I_2, ... I_n are corresponding indices for preceding years weighted by the numerical factor a^i ($a < 1$). The annual index I_i is given by

$$I_i = \frac{1}{2} \sum_{j=1}^{2} \frac{x_j - \bar{x}_j}{R_j} \qquad (3)$$

where x_1 = mean temperature (March to July), x_2 is total precipitation (August to October and March to July), and where $\bar{x}_j$ and R_j represent mean values and ranges, respectively, for each variable for the period of record (1886-1982).

Because of the factor a^i in (2) the contributions of preceding years decreases with increasing age and the sum can be terminated in practice at n = 3 to 5 for $a < 0.5$. The unknown weight a was estimated by linear correlation between D and the history book frequencies from Figure 4 for 1910-1960. The highest linear correlation was attained with $a = 0.4$. Because of the need for this step it must be emphasized that the index D was not developed independently of the data with thich it is to be compared although it utilizes only measured temperature and precipitation data at Calgary and Medicine Hat.

The drought index D is shown in Figure 6. It accounts for about 65 percent of the variance of community history dry year reports shown in Figure 4. Correlation coefficients between reported dry year frequencies between 1910 and 1960 and various components of D are shown in Table 1.

The index D successfully identified 1910 and 1919 as the two driest years and it exhibited the desired tendency for grouping of dry and wet years. It is possible that D could be refined and improved by the addition of fall temperature data and by the addition of data from other weather stations. A more stable index could be devised by replacing R_j by the standard deviation. However, a more serious shortcoming is the lack of an independent data sample for test purposes. Most of the variance in reports of dry years was associated with very few years in which unusually high temperatures and low precipitation were combined in critical sequences of months. A much larger data sample is needed for testing such rare events.

Table 1

CORRELATION COEFFICIENTS BETWEEN COMMUNITY HISTORY REPORTS OF DRY YEARS AND THE DROUGHT INDEX BASED ON TEMPERATURE AND PRECIPITATION DATA FROM CALGARY AND MEDICINE HAT (1910-1960)

Variables		Correlation Coefficient
Mean temperature (x_1) only		0.47
Precipitation (x_2) only		0.67
Combined temperature and precipitation:	a = 0.0	0.71
	a = 0.2	0.75
(Figure 6)	a = 0.4	0.79
	a = 0.6	0.79

It is unlikely that large negative values of the "drought" index D can be expected to correspond closely to community history reports of wet years. Descriptive comments in these books suggest that the primary impact of wet years resulted from unusually heavy summer precipitation (from July to August or September) which inhibited fieldwork and crop ripening. An outstanding example occurred from 1899 to 1903 in central and southern Alberta (Roe, 1954). The years

1951-1956 with large negative D values were not remembered by the public as outstanding wet years.

In following subsections frequency distributions of community history reports of several additional outstanding weather events are presented. The reports serve to identify the events but more work is needed to reconstruct the events and their impacts in detail.

3.3 Killing Summer Frost

The most remembered killing summer frost occurred between 21 and 25 July, 1918 from the Peace River region through central Alberta to Kamsack and Swift Current, Saskatchewan (Figure 7). Minimum temperatures of -5°C to -10°C were reported between Edmonton and Lloydminister. Crop and garden losses were enormous and the subsequent stench of rotting vegetation was recalled by many.

3.4 Severe Hail and Destructive Winds

The frequencies of reports of destructive hail, tornadoes, and other destructive winds are shown in Figure 8. With the exception of 1911 the time distribution of severe hailstorms is fairly uniform from 1910 to 1960 and shows no evidence of serious sampling bias in that period. The large number of reports in 1911 resulted mainly from one series of storms along a west-to-east strip from western Alberta through the Hand Hills and Buffalo Hills to Saskatchewan and a second outbreak from Claresholm to Foremost. Both occurred near harvest and caused major crop devastation. Both were characterized by unusual destructive energy and large hail swaths.

The frequency distribution of tornadoes, in contrast to those of severe hail storms and non-tornadic winds, shows a systematic drop in frequencies with time. This is attributed to sampling bias caused by increasing average farm sizes and declining rural population density. With the exception of 1927 the highest frequencies occurred from 1910 to 1920 at the time of maximum rural population density in central and southern Alberta. The tornadoes reported in community histories are those which caused building loss or damage and, therefore, the numbers reported depend directly on the number of occupied farmsteads.

Most of the 30 to 40 tornadoes reported in Alberta in 1927 occurred on July 8 and 9 - a two-day outbreak unique in the recorded history of the province. Five settlements including Vulcan and Rocky Mountain House were struck. More than 60 farmsteads suffered building losses ranging from grain bins to large barns ahd homes. Three persons lost their lives and several were injured.

Non-tornado destructive winds include cold fronts, chinooks, valley winds, and thunderstorm downdrafts. The cold front of November 22, 1930 was memorable for the severe building damage which occurred intermittently between Lac Ste Anne and the Saskatchewan border.

3.5 Blizzards and Spring Snow Storms

The late spring snow storms of 1903, 1910, and 1919 were appreciated by many for their contributions to soil moisture. Unfortunately, the May storms resulted also in major livestock losses. The storm of June, 1910 was accompanied by strong winds with widespread, though minor, property damage. According to many residents, it provided the only significant summer precipitation in that extremely dry year.

The winter blizzards of 1938, 1948, and 1951 are remembered most for severe disruptions to transportation and communication and for huge 5 to 8 metre drifts that accumulated over rail lines, farmsteads, and other obstructions. The impact areas were well defined by the community histories and were typically in strips 500 km by 200 km. Further work is needed to relate the atmospheric structure of these storms to their areas of impact.

4. Summary

Severe winter and drought indices derived from combinations of temperature and precipitation data from three weather stations with long-term records in central and southern Alberta were found to correlate reasonably well with the frequencies of community historybook reports of these events when some attention was paid to the nature of their impact on rural life, property, and activities. These results lend credibility to the use of such reports in identifying severe small-scale weather events for which weather station data are rarely available. A list of notable weather events based on high frequencies of community history reports is given in Table 2.

Table 2

ALBERTA WEATHER EXTREMES DERIVED FROM
COMMUNITY HISTORY REPORTS 1880-1960

Weather Event	Date
Severe winter	1906-07, 1919-20
Dry year (southern Alberta)	1910, 1919
Wet year	1901
Widespread hail damage	1911
Tornado outbreak	July 8, 9, 1927
Cold front winds	June 1, 2, 1910; November 22, 1930
Killing summer frost	July 21-25, 1918
Ice storm	April, 1932
Dust storm	June 2, 3, 1937; May 5, 1945
May snowstorm	1903, 1919
Winter blizzard	March 1938; March 1951

5. References

Barnes, S. and E.S. Hopkins, 1930: Soil moisture and crop production. Bulletin 130, Dominion of Canada, Department of Agriculture.

Hopkins, J.W., 1936: Weather and wheat yield in western Canada. II Influence of pre-seasonal precipitation on plot yields. III Relation between precipitation and agricultural yield. Can. Journal of Research, 14, 229-244.

Roe, F.G., 1954: The Alberta wet cycle of 1899-1903: A climatic interlude. Agricultural History, 28, 112-120.

Williams, G.D.V., 1962: Prairie droughts: The sixties compared with thirties. Agricultural Institute Review, 17, 16-19.

Figure 1. Frequency distribution of community history reports of severe winters in central and southern Alberta.

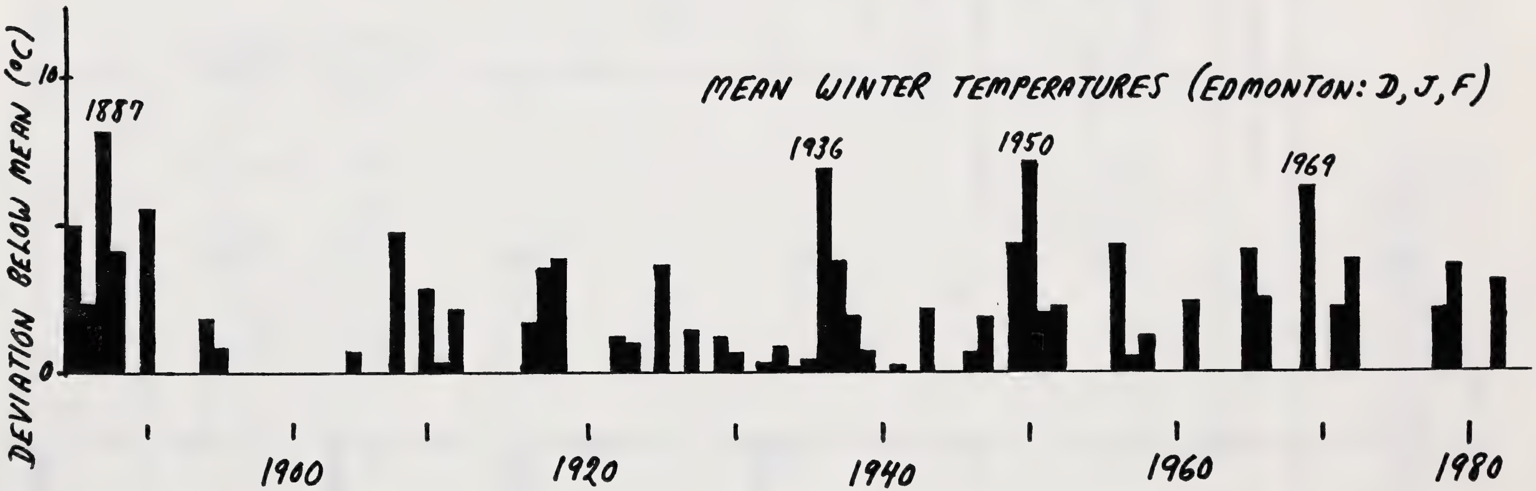

Figure 2. Winter temperatures at Edmonton expressed as deviations below the long-term mean.

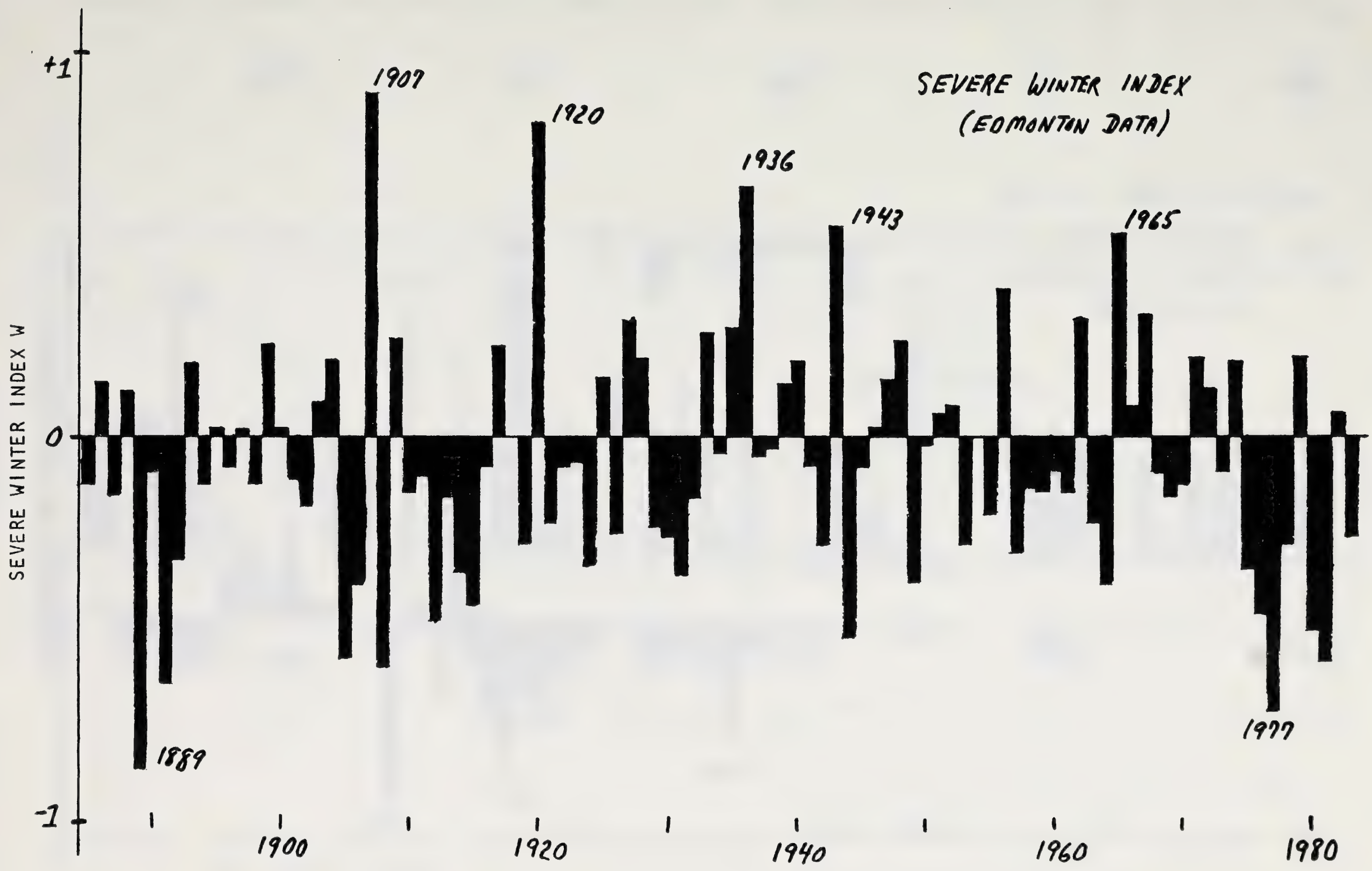

Figure 3. Severe winter index W derived from Edmonton temperature and snowfall data.

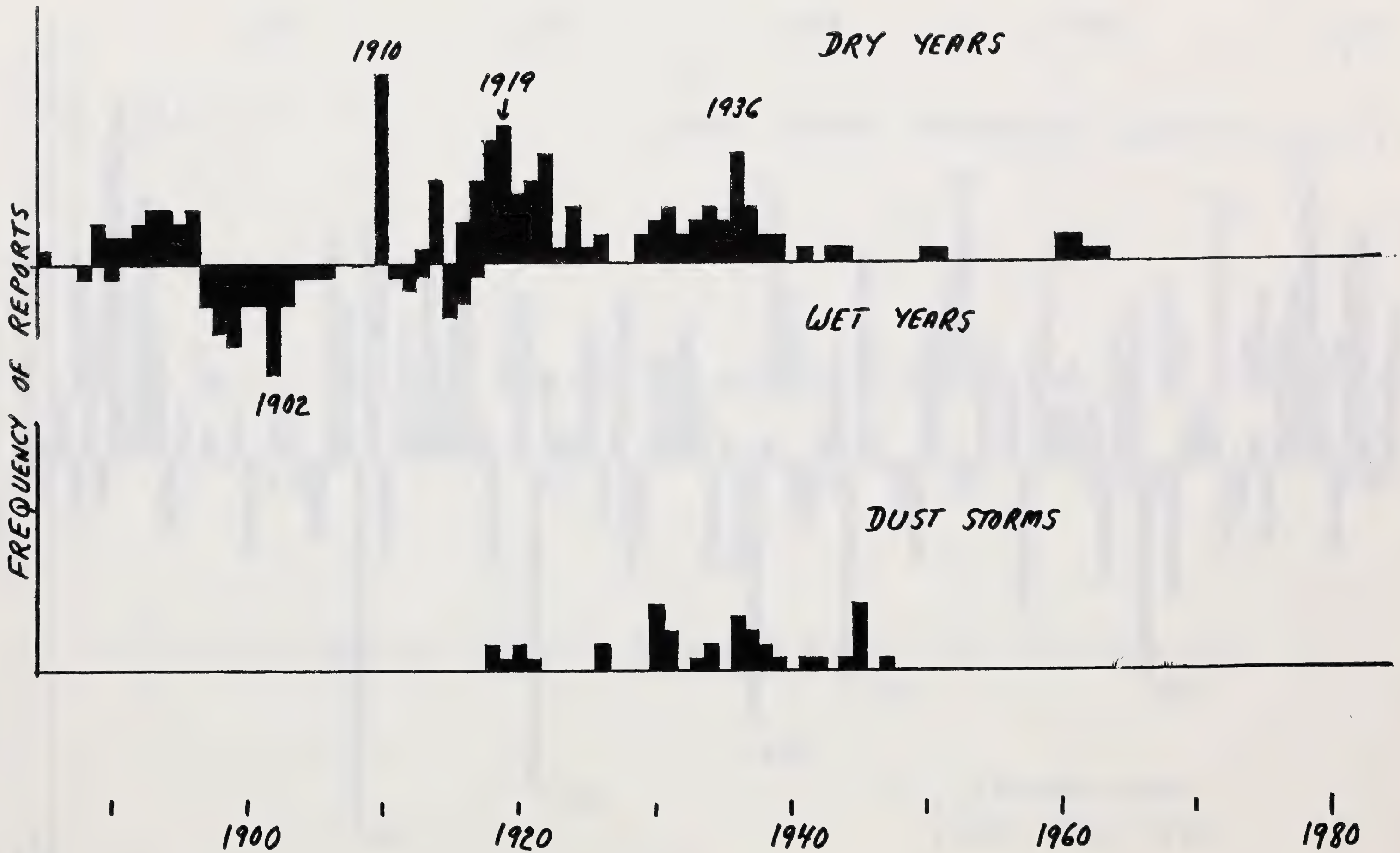

Figure 4. Frequency distributions of community history reports of dry years, wet years, and dust storms.

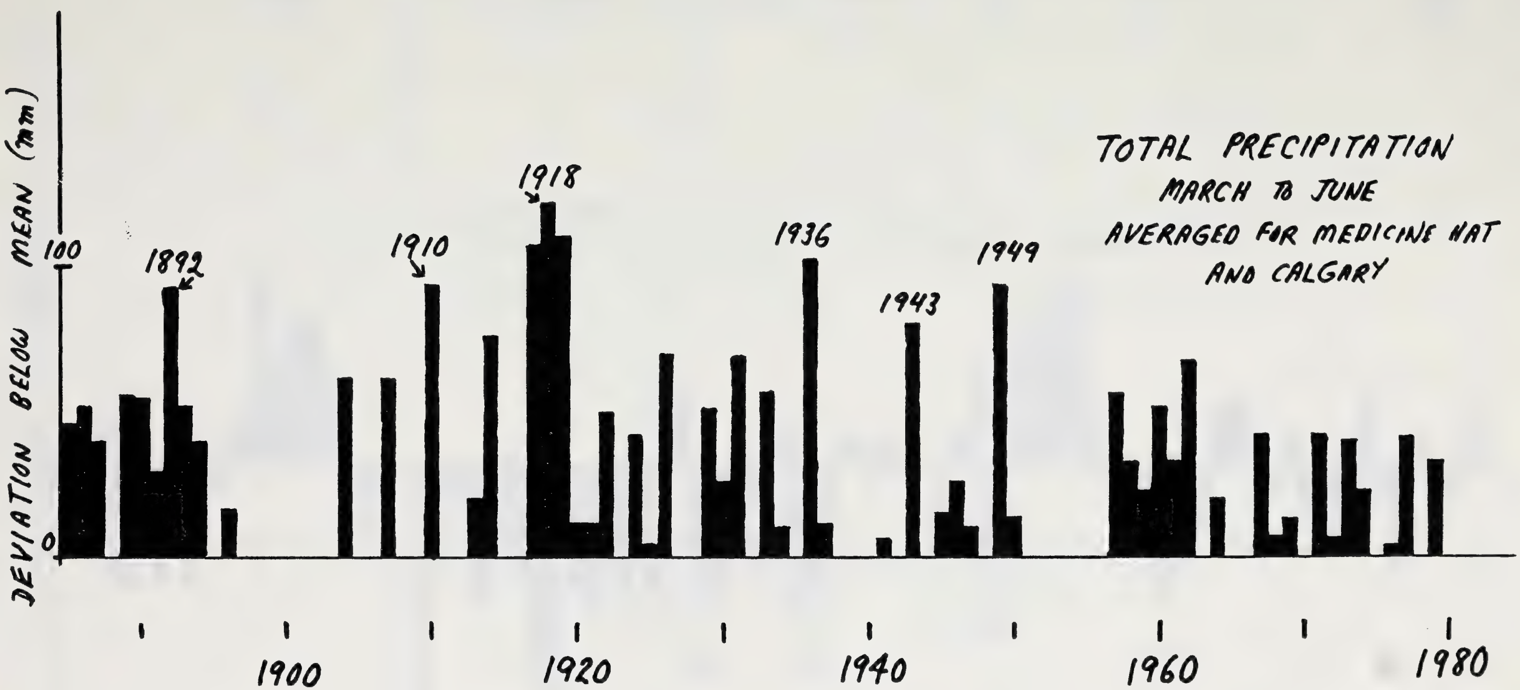

Figure 5. March to June total precipitation for Medicine Hat and Calgary expressed as deviations below the long-term mean.

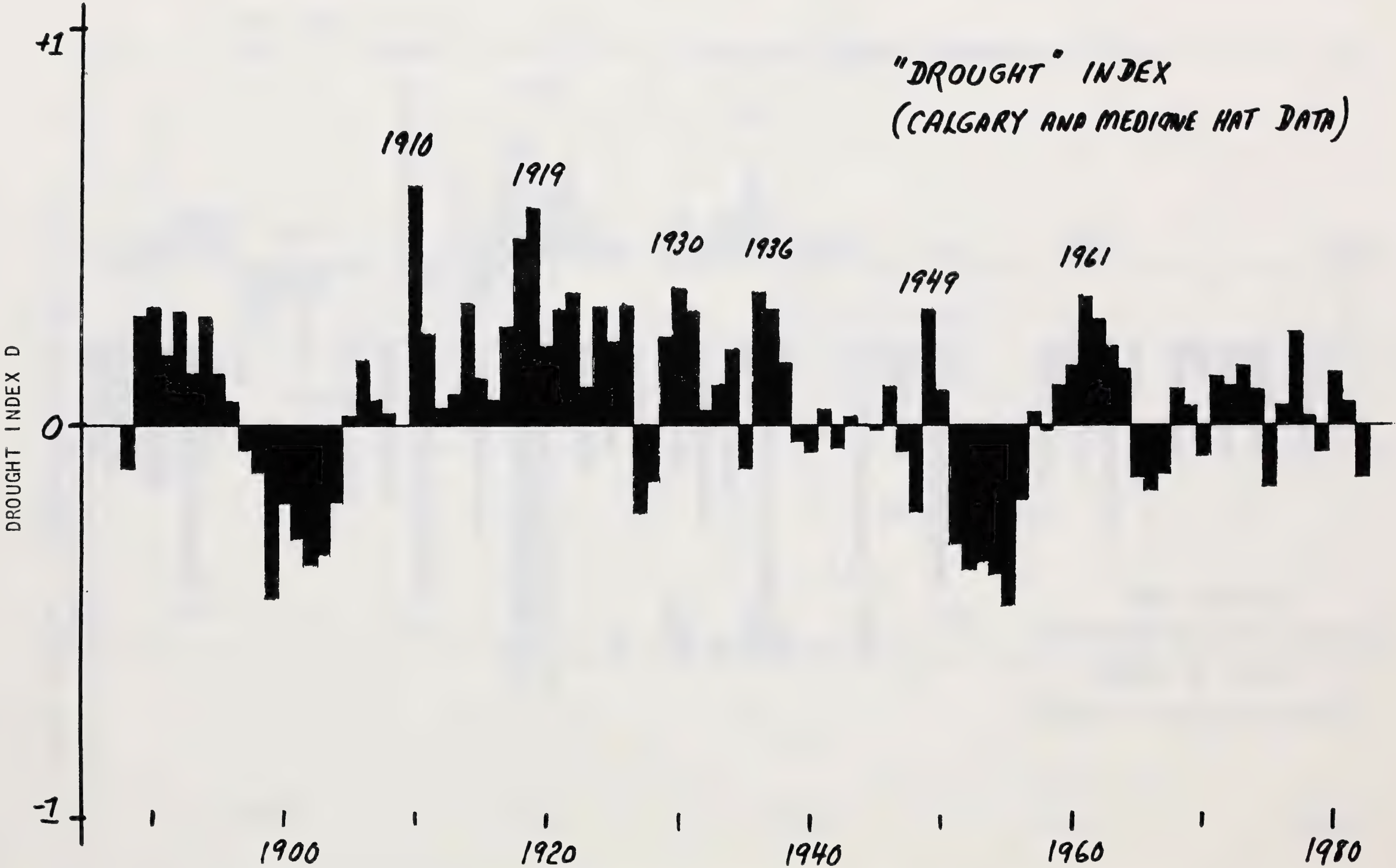

Figure 6. Drought index D derived from Medicine Hat and Calgary temperature and precipitation data.

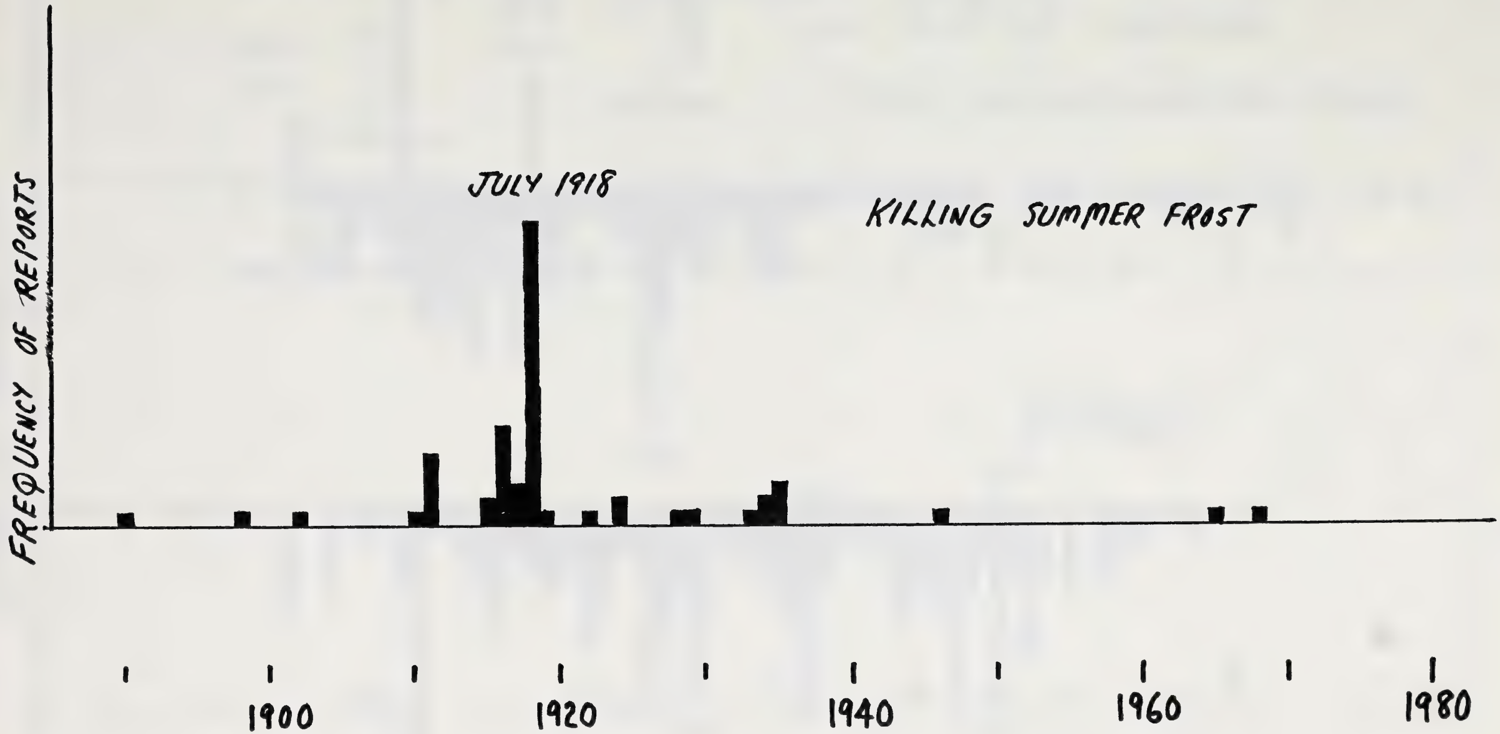

Figure 7. Frequency distribution of community history reports of killing summer frosts.

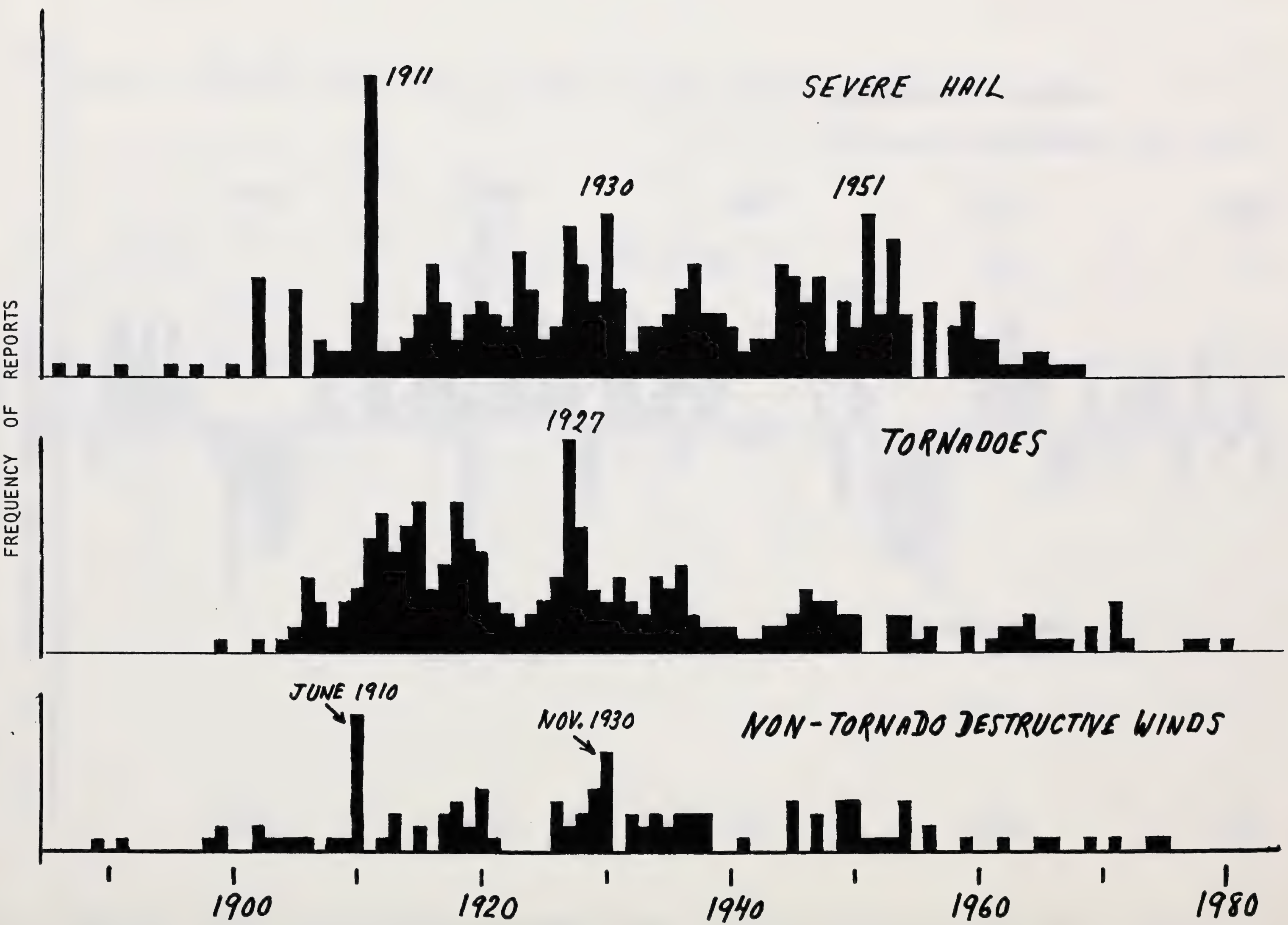

Figure 8. Frequency distributions of community history reports of severe hail storms, tornadoes, and

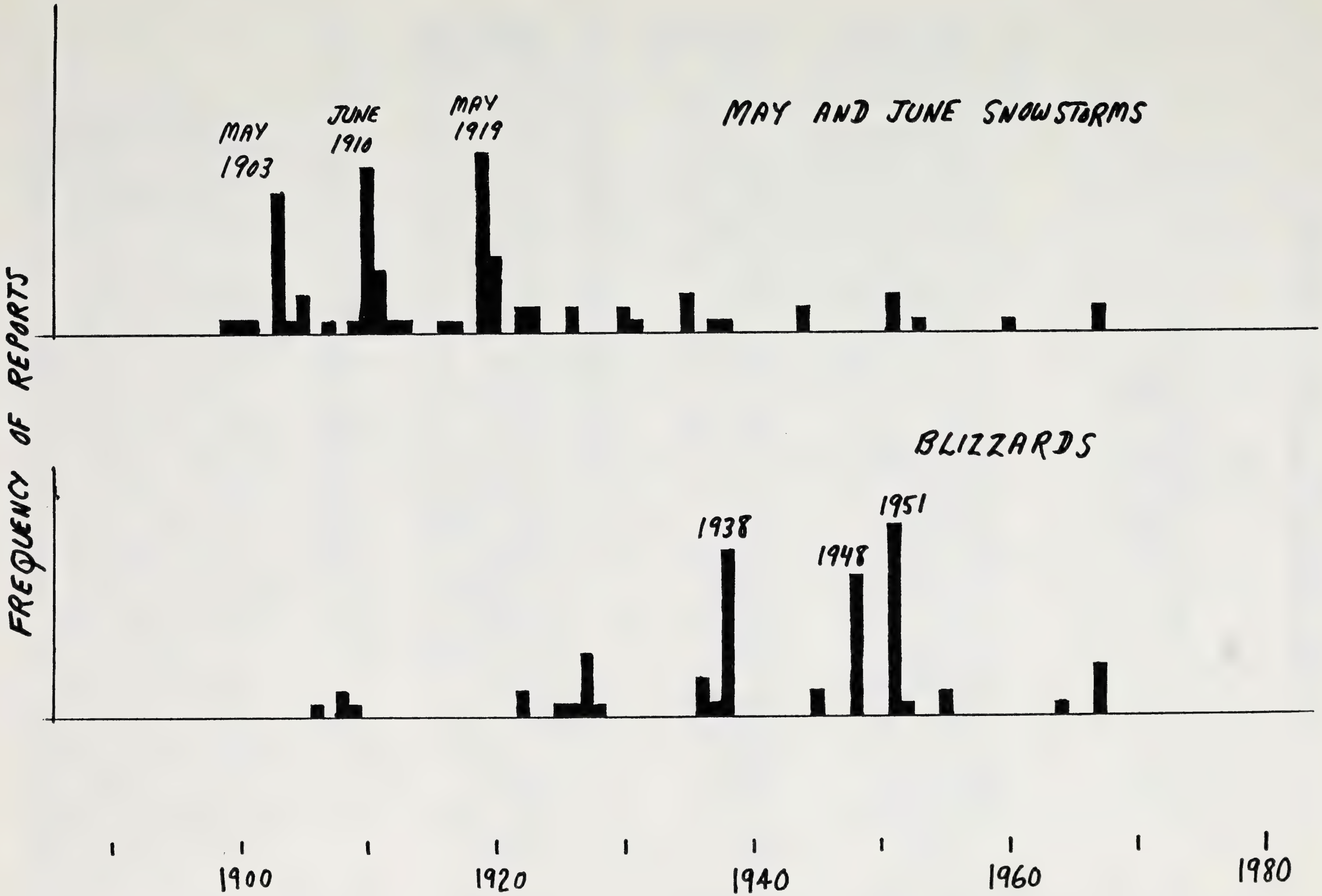

Figure 9. Frequency distributions of community history reports of May and June snowstorms and blizzards.

EDMONTON'S CLIMATE: EARLY PERCEPTIONS AND PRACTICAL SEASONAL DIFFERENTIATIONS

by

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Introduction

The City of Edmonton has a northern mid-latitude continental climate. It is located within the transition zone between the prairie grasslands and the northern forests. As such, the City usually experiences the warm summers of the prairies and the cold winters of the boreal forest. Variability is a dominant characteristic of the climate within the Edmonton region. Large departures from the long-range averages can be expected from day to day, month to month, and year to year.

Edmonton is a relatively young city. Historic climate records go back to 29 December, 1879 when Mr. G.S. Wood, a telegrapher, installed the first meteorological station in the city. Daily observations commenced on 11 July, 1880 with minor interruptions when Mr. Wood was repairing the telegraph line.

Early Perceptions of Edmonton's Climate

The first wave of settlers arrived in Edmonton in the late 1870s and early 1880s. Their knowledge of Edmonton's climate was limited. The fact that they decided to farm the district must originally have been based upon bioclimatic considerations. The only other stations on the Prairies with empirical climate data were in southern Manitoba, where the natural vegetation had many similarities to the Edmonton region.

In April 1883, when there was only 3 years of actual climate data for the City, the editor of the **Edmonton Bulletin** wrote:

> "Probably the greatest drawback that there is to the rapid filling up of the North-West (Edmonton region) by immigration from eastern Canada and European countries is the fact that the winter climate is cold - a number of degrees colder than that to which the people of these countries have been accustomed. It avails not to tell them that the greater cold does not cause any extra suffering, that a man can be just as comfortable in the North-West than in any part of easternt Canada. It is a fact tha there is less suffering, less disconfort, less danger and less death from cold in the

North-West than in any part of eastern Canada ... It is not the number of degrees of cold alone that does the damage. It is the circumstances that accompany the cold, and the condition of the person or animal exposed to it ... In the north the consitution of both men and animals is built up and strengthened naturally in order to prepare them for the cold winter which is certainly before them, while in the south the summer climate is enervating, and as the ordinary weather of winter is not cold no such strengthening process takes place, and when a "norther" comes, carrying the cold and snow on the north over the warm plains and amongst the herds of the south, the consequence is terrible suffering and many deaths ...

It is not by any means certain that the hot weather of the south is more pleasant than the cold weather of the north to persons who have been accustomed to the latter, while it is very certain that the hot weather is injurious to the health, while the cold weather is conducive to health and perfection of physical development ... It is notorious that the farming community of the southern states do not live nearly as well, do not enjoy life nearly as much, and are not nearly as prosperous as the people of the north. The southerners name indeed has become a by-word for all that is ignorant, lazy, and thriftless ... As the necessity for exertion is decreased so the power to enjoy is lessened ...

If the people of the north then are more healthy, more happy, and more progressive - better men both physically and intellectually - than those of the south; if the cool climate is to a great extent the cause of this, being better suited to the perfect development of the human race...is it not the height of folly for the papers of eastern Canada to decry the climate of the northwest on account of its being cold, when it is in reality but little colder than that in which they live .... It is the north where the great nations of the earth are bred - those that lead in war-like power and peaceful industry. And herein the Canadian North-West, with its fertile soil, its healthy climate, its free institutions, its enterprising people, we may confidently look to see established a nation that shall combine bodily health with mental vigor to such a degree that it shall yet lead the world in all that is great and good. (**Edmonton Bulletin**, Volume 4, Number 25, 21 April 1883).

It would be difficult to back up some of the editor's claims. Never-the-less, statements such as his may have been influential in luring settlers to the "North-West", as it was called then. And, more than a hundred years after a similar sentiment endures. While reflecting upon the passing of the seasons the editor of the **Edmonton Journal** (2 August 1983) mused that the character of Edmontonians "... is drawn from the land ... [They] appreciate the rhythm of nature here, which becomes the rhythm of the people, too."

The Seasons in Edmonton

The climate of Edmonton naturally corresponds to conditions experienced at other northern prairie or southern boreal forest sites, simply because they are all affected by many of the same large-scale atmospheric features. The only other region in the world that has a climate similar to Edmonton's is on the West Siberian Plain in the Union of Soviet Socialist Republics. In these areas the standard seasonal periods, which are based on solar or monthly criteria, are not generally applicable. The following is a relatively practical approach to seasonal differentiations for Edmonton.

A season is a distinct portion of the year with uniform climate characteristics. The City of Edmonton has two periods in which climate conditions are relatively uniform - winter and summer. Spring and fall in the seasonal context are not distinct in central Alberta since their weather on any given day is often similar to either summer or winter. Rarely is there an orderly transition from summer to winter or winter to summer.

The winter-summer duality of Edmonton's seasonal regime can be demonstrated using various climate parameters. Temperature (Figure 1) has two distinct periods, one mild, the other cool, that have relatively uniform conditions. They are separated by short transitions in which the temperatures are rapidly increasing or decreasing.

The distribution of total monthly precipitation in Figure 2 illustrates a relatively wet period during the warmer months and a dry period during the cooler months. The change-over months, April/May and September/October , have the greatest variability in precipitation as a function of their respective monthly means. Consequently, in any particular year, these months can often be grouped with either the wet or dry periods of the year. The occurrence of snow can also be used to divide the year. The warmer five months rarely have measurable snowfalls. The cooler five receive nearly all their precipitation as snow. The remaining two months, April and October, average half their totals as snow.

Winter in Edmonton is characterized by a persistent snow cover. Outdoor activities that require a blanket of snow or a sheet of ice can be conducted throughout this period. The beginning of winter is defined as the average date when the mean daily maximum temperature dips below freezing, which is normally November 16. From this date on, snow that falls will usually stay for the season. Winter continues until the mean daily maximum temperature rises to the thawing point, usually March 17. Snow remains on the ground for a period after this date but winter activities cease due to patchy snow cover and melting ice.

Summer in Edmonton is characterized by warm weather. Outdoor events are not limited by temperature but occasionally rain or wet ground can restrict these activities. The season is considered to begin when the mean daily maximum temperature reaches the 18°C threshold, May 19, and it ends the day before

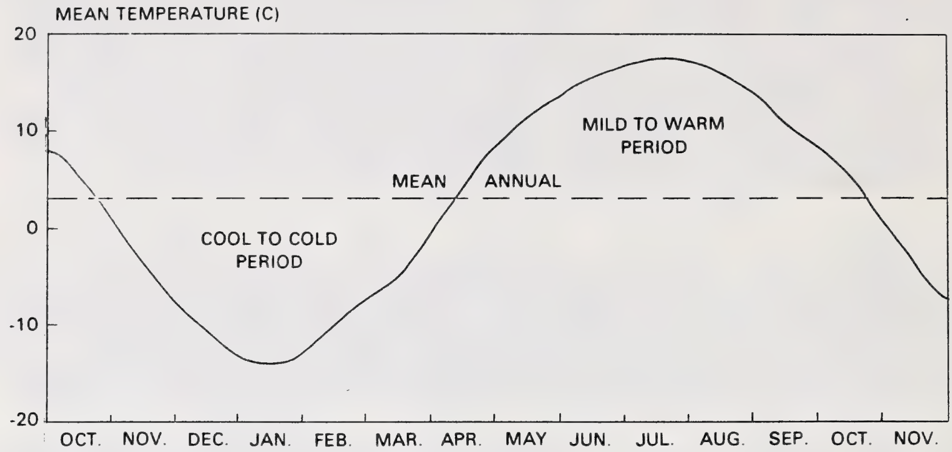

Figure 1: Annual temperature regime in Edmonton.

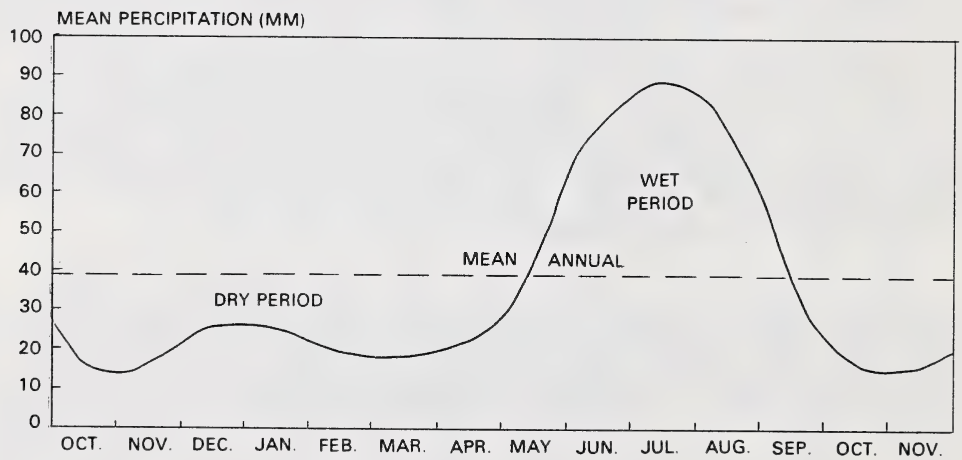

Figure 2: Annual precipitation regime in Edmonton.

the temperature drops below this value, September 6. By coincidence, the beginning and ending of summer often correspond to Canada's Victoria and Labor Day holiday weekends.

Spring and fall are defined as the periods when mean daily maximum temperatures are at or above 0°C but less than 18°C. Any given day during these transitional seasons may have weather that is more characteristic of summer or winter. The closer the date is to the beginning or ending of summer or winter, the greater the probability that the transition period will have conditions similar to that season. Constraints on most outdoor activities can be expected during these intervals, especially during the spring transition. In late March and early April the snow and ice, if there is any, will not be suitable for winter recreation. Yet, the presence of the melting snow pack inhibits dry-land activities. Golf courses and unimproved hiking or jogging trails along the river will not be satisfactory for use. During the fall transition many of summer's more vigorous activities can be conducted. Dry weather during this period promotes these activities until the arrival of winter's permanent snow cover.

The relationship between calendar time and seasons is depicted in Figure 3. The concept of two dominant seasons separated by transition periods can be visualized in the figure. Winter and summer are both relatively long compared to the two transitions. Winter averages 121 days while summer averages 111 days. The spring and fall transitions are brief, at 63 and 70 days, respectively.

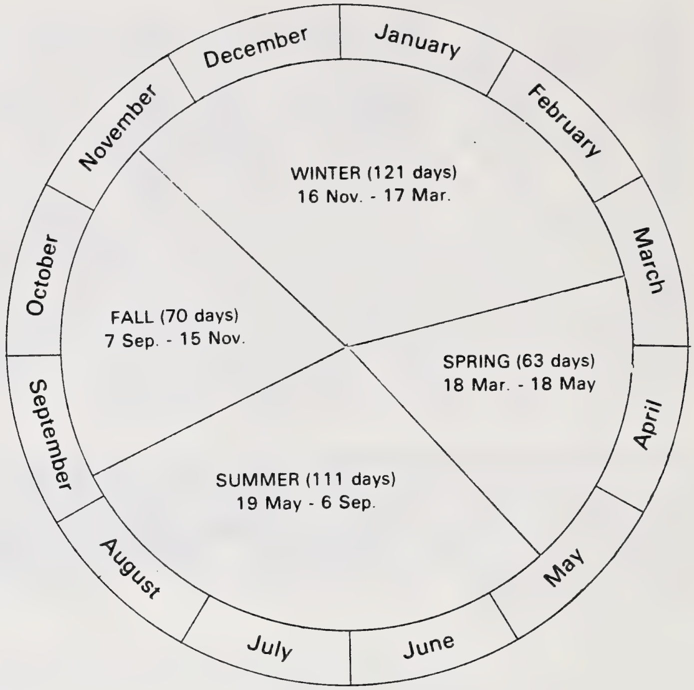

Figure 3: Distribution of seasons at Edmonton.

SNOW CLIMATOLOGY OF THE SOUTHERN CANADIAN ROCKIES

by

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Abstract

A preliminary analysis of the snow climatology of the Rockies south of Banff, Alberta is presented. This background study is part of a planned research effort to determine the modification potential of orographic cloud systems during the snow season. Its purpose is to assess the current snowfall climate data to determine the general character of snowfall within the possible study area.

Precipitation data from a variety of sources were analysed including A.E.S. climate stations and snow courses from Alberta, British Columbia and Montana. The temporal, altitudinal and spatial characteristics of snow are examined. A peak in snowfall amounts and frequency is found in January for the mountain A.E.S. stations. Snowpack water equivalent reaches an averge maximum value in late spring. A strong correlation of snowfall with elevation is indicated by linear regression models. The spatial variability is quite complex with maximum annual snowfall amounts occurring along the Alberta-B.C. border regions. Recommendations for future research approches are given.

1.0 INTRODUCTION

The winter snowpack of the southern Canadian Rockies is the principal water resource for irrigation agriculture in southern Alberta. Future expansion of this agriculture and accommodation of other water-based requirements depends on careful management of this region's water resources (Environment Council of Alberta, 1982). Supplementing this water resource by increasing the snowpack storage may assist in such management.

The Alberta Research Council has initiated a preliminary project to examine the feasibility of supplementing the snowpack through the controlled use of cloud-seeding techniques. The project's initial aim is to measure and analyze the precipitation processes of the snow-producing orographic clouds. An instrumented research aircraft is being used to assess the efficiency of these cloud systems to determine if a potential "seeding window" exists (Vardiman and Moore, 1977). Preliminary analysis of upper-air data indicates that such a "window" of suitable temperature and

moisture conditions may exist in the early fall or late spring (Renick et al, 1979).

The project study area straddles the Alberta-British Columbia border (Fig. 1). Knowledge of the characteristics of snowfall within this general area of the southern Canadian Rockies would assist in project design. Information on where and when snowfall occurs and which periods correspond to the "seeding window" would be particularly useful. In addition information on the spatial distribution of snow would be useful for the design of a network for any potential seeding program that may be initiated.

The general snow regime of the southern Canadian Rockies has not been previously analyzed. Detailed analyses of snowfall distribution over small areas have been done (Storr, 1973; Golding, 1974). The general climate of the contiguous mountain National Parks has also been summarized (Janz and Storr, 1977). On a larger scale, the frequency of extreme snowfall events for the province has also been investigated (Nkendirim and Benoit, 1975). The lack of snowfall analyses for the southern Canadian Rockies prompted this preliminary approach.

This paper first identifies and discusses the type and limitations of published snow data sources. An analysis of the temporal variation of snow follows. The important altitudinal variation of snow is then discussed. The analysis is completed with a brief examination of the regional variation of snowfall. Finally, recommendations on future assessment analysis needs are offered.

2.0 EVALUATION OF SNOWFALL DATA SOURCES

2.1 Data Sources

Two types of data were used for this preliminary analysis; monthly precipitation totals (cm) and seasonal snow depth measurements (mm water equivalent). Monthly snowfall values were abstracted from published monthly climate normals for Atmospheric Environment Service climate stations (Atmospheric Environment Service, 1951-1980). These averaged data represent the 30-year precipitation normal base don data from 1951 to 1980. Data synthesis techniques have been applied by A.E.S. in the normalizing procedure to accommodate missing data. This data set is considered to be the most complete, and is the principal data source for subsequent analysis.

Seasonal snow depth water equivalent values were abstracted from the published snow survey measurement programs of Alberta, British Columbia and Montana. These measurements are generally mde on a monthly basis from January to May (Alberta) or June (B.C. and Montana). Measurements are taken at the beginning of the month. An additional mid-May measurement may be included for some stations.

The sources, number of stations, years of record and average site elevation are summarized in Table 1. Mountain climate stations are defined as those stations located within the physiographic region of the Rocky Mountains or Foothills. An additional 25 prairie climate stations are identified for mapping purposes.

2.2 Data Source Analysis

The map showing the network of AES climate stations and snow survey sites (Fig. 2) includes the 6 000 ft. (1 825 m) contour as an indicator of terrain height. Two general features are notable. A sparse, clustered network is indicated with an approximate value of about one station per 800 sq. km. Secondly, most of the stations are at lower elevations with only a few above the contour. These characteristics underscore the difficulty in providing a detailed and confident assessment of the snow climate.

The data sources vary substantially as to length of record and seasonal coverage. The AES climate stations generally have a longer record length. Figure 3 indicates this by showing the number of A.E.S. stations as a function of measurement record length. A bi-modal distribution is evident with peaks of station installation activity being at 20 and 60 years benchmarks. For climate assessment, the AES network record length seems quite adequate.

The different requirements and seasonal character of the snow surveys result in a data set more limited and variable than that of the A.E.S. stations. This variability, evident in both record length and number of stations, is shown for the Alberta and B.C. snow survey sites (Fig. 4). The generally longer record of B.C. data, particularly in the early months of the survey, is apparent.

3.0 RESULTS

3.1 Seasonal Snow Variation

A plot of the calculated average monthly snowfalls for all 56 mountain climate stations within the project region shows that snowfall increases from a minimum in the autumn to a monthly maximum of 50 cm in January (Fig. 5). This mid-winter maximum may reflect the higher efficiency of precipitation processes with colder temperatures and sufficient atmospheric water supply. The platesau of 30 cm to 40 cm through the late winter and early spring months gives way to the rapid decrease in late spring. The significant spring contribution suggests that the spring temperature-moisture "seeding window" may occur during periods of high natural precipitation.

Snowfall frequency (Fig. 6) follows a pattern similar to that of snowfall amount. The January peak of about 10 snow-days is folloed by a decline that accelerates rapidly during the late spring. The lower April snow-day

frequency, combined with the higher snowfall amount, suggests that in the late spring fewer but larger snowfalls occur.

Snow water equivalent data give a more limited view of actual snowfall, but they do provide relevant information on the seasonal character of snowpack water storage. The seasonal variation of the combined Alberta, B.C. and Montana data (Fig. 7) shws that over half (approximately 250 mm) of the maximum snowpack accumulates before the measurement program begins in January. Additional contributions throughout the winter-spring period results in a peak snowpack of 500 mm on May 1. A rapid depletion of the snowpack in late spring, which results in an increase in water flow, is also evident.

3.2 Snow Variation with Elevation

The complex topography and higher elevations of the mountain regions substantially affect snowfall characteristics. The cooler temperatures at higher eleations enhance snowfall occurrence and snowpack persistence. Station data were examined as to their variability with elevation to determine the relative importance of this factor. A plot of average annual snowfall against station elevation for the mountain AES climate stations (Fig. 8) shows a strong trend to increased snowfall amounts at higher elevations. Snowfall at lower elevation sites (e.g. 700 m MSL) may be less than one-half the annual snowfall at higher sites (e.g. 1 500 m MSL). Included in Figure 8 is the calculated linear regression relation which predicts snow dpeth from elevation. The high, significant correlation coefficient (0.73) suggests that about 50% of the annual snowfall variation is explained by station elevation.

The seasonal variation of snowfall with elevation as measured by the correlation coefficient is more pronounced (Fig. 9). The twin peaks of high correlations in the early autumn and late spring may reflect the role of cooler temperatures at higher elevations during those periods. Snow at higher elevations would settle and remain first, and melt last, at higher elevation sites. The mid-winter low correlation reflets the ubiquitous cold temperatures within the region. The still-significant correlation during the warmer season may reflect the influence of complex topography and cooler temperatures at higher elevations.

The elevation-snow relation obtained snow survey data is less well-defined than that for average annual snowfall. Greater variabillity is indicated, particularly with the inclusion of the Montane data (Fig. 10). The Montana values seem to be consistently higher than those for Alberta and B.C., and may reflect differences in network criteria, data measurement procedures and quality control. The correlation coefficient of 0.59 (0.38 with Montana) suggests that only about 35% of the snow depth variation can be explained by site elevation. The complex effects of topography on snow storage may overshadow the effect of elevation on snow precipitation patterns.

3.3 Snow Spatial Variation

An analysis of the climate station data was conducted to examine the gross spatial characteristics of the regional snowfall. The sparse measurement network and complex terrain makes any data interpolation between points questionable but some patterns may be apparent. Figure 11 shows the computer-contoured average annual snowfall in the project region. This contouring includes prairie stations and is based on a one-pass weighted-average data smoothing.

The map shows that maximum snowfall amounts occur over the mountain regions, as expected. A fairly steep gradient over the drier Columbia river valley is indicated. Snowfall amounts gradually decrease across the Alberta foothills and into the lower prairie regions. The effect of the limited and irregular network is suggested by the apparent lower values over the divide southwest of Banff. This feature may be due more to network sparseness rather than any real precipitation patterns.

The variability of snowfall frequency is indicated by the annual number snowfall days (Fig. 12). Two data-smoothings were performed to minimize the significant variability of this data. A maximum frequency over the higher mountain regions is indicated. The complex pattern suggests a general tendency for the number of snowfall days to decrease eastwards across the prairies.

The high correlation of snowfall amount with site elevation may mask other factors influencing snow distribution. The previously noted snow-elevation regression model approach was used to "subtract" the elevation influence from the annual station values. Elevation-predicted annual snowfall amounts were determined for each station and the ratio of the ctual to predicted values calculated. The contour plotting of these actual/predicted ratios is illustrated in Figure 13 (two smoothings). The plotted ratio can be used to suggest whether other factors may be responsible for snowfall variation. Values in excess of one indicate larger than expected snowfall values. Conversely, values less than one suggest less than expected snowfall values.

A general trend of underestimation towards the southwest and overestimation in the northeast is suggested. The excessive values for the southern part of the region may reflect the area's closer proximity to maritime moisture sources. The lower-than-expected values for the north may indicate drier continental climate patterns.

4.0 CONCLUSION

This brief preliminary analysis has outlined some of the general characteristics of the snow climate of hte southern Canadian Rockies. The seasonal strong season character of snowfall with a mid-winter peak has been indicated. The maximum snowpack depth in late spring, and subsequent

rapid melt, has also been delineated. A strong correlation with site elevation provided equations for predicting snowfall and average snowpack water equivalent. The spatial distribution of snowfall has been shown to be quite variable with maximum values being indicated along the higher elevations.

These results give a preliminary overview of the snowfall climate of the snowpack study region. The temporal trend of snowfall and snowpack water equivalent suggests that a substantial contribution is made during the late winter and spring. The spring "seeding window" (Renick et al, 1979) mayu then occur during this period of substantial natural precipitation. This suggests that a potential for snowpack augmentation within the study area may occur during the spring months.

The study has also indicated the difficulty of assessing the snow climate due to the sparse network and limited snow survey record length. The importance of site elevation is also indicated. Based on these preliminary results, a measurement network for the region cannot be confidently specified.

A more detailed analysis of the precipitation data would provide a more confident climate assessment. Examination of daily records from the climate network would assist in this by identifying individual precipitation events. A time series analysis of the data may delineate any trends in the snow data. Finally, a cloud climatology of the region would provide relevant information on the snow-producing clouds of the region.

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Figure Captions

Figure 1. Alberta Research Council Snowpack Project Area

Figure 2. Network of A.E.S. climate stations and provincial snow survey sites in the southern Canadian Rockies area.

Figure 3. Frequency of record length for 57 A.E.S. mountain climate stations

Figure 4. Average record length of Alberta and British Columbia snow survey courses throughout measurement season. The seasonal standard deviations is also given.

Figure 5. Average monthly snowfall over the year for 57 mountain A.E.S. climate stations.

Figure 6. Average monthly number of snowfall-days over the year for 57 mountain A.E.S. climate stations.

Figure 7. Average snow water equivalent over the measurement season for 70 Alberta, B.C. and Montana snow courses.

Figure 8. Variation of average annual snowfall with station elevation for 57 mountain A.E.S. climate stations. The calculated linear regression least squares fit and correlation coefficient are also shown.

Figure 9. Seasonal variation of the correlation between average monthly snowfall and station elevation for 57 A.E.S. climate stations.

Figure 10. Seasonal variation of average snow water equivalent with elevation for 70 Alberta, B.C. and Montana snow courses. Linear regression lines and correlation coefficients calculated both with and without the Montana data are alsos shown.

Figure 11. Average annual snowfall for general project area (82 A.E.S. climate stations).

Figure 12. Average number of annual snow days for general project area (82 A.E.S. climate stations).

Figure 13. Ratio of actual annual snowfall to elevation regression model predicted annual snowfall for general project area (82 A.E.S. climate stations).

Table 1

SNOW DATA SOURCES USED IN CLIMATOLOGICAL ANALYSIS

Source	Type	Sites	Mean Record Length (Years to 1980)	Mean Elevation (m MSL)
AES Climate Stations	Monthly Snowfall (12)			
Mtn./Foothills		57	30 Normals	1 182
Plains		25	30 Normals	1 024
Alberta Snow Survey	Seasonal (5) (Feb.-June)	28	9.3	1 857
B.C. Snow Survey	Seasonal (7) (Jan.-June)	28	13.7	1 619
Montana Snow Survey	Seasonal (7) (Jan.-June)	15	9.1	1 606

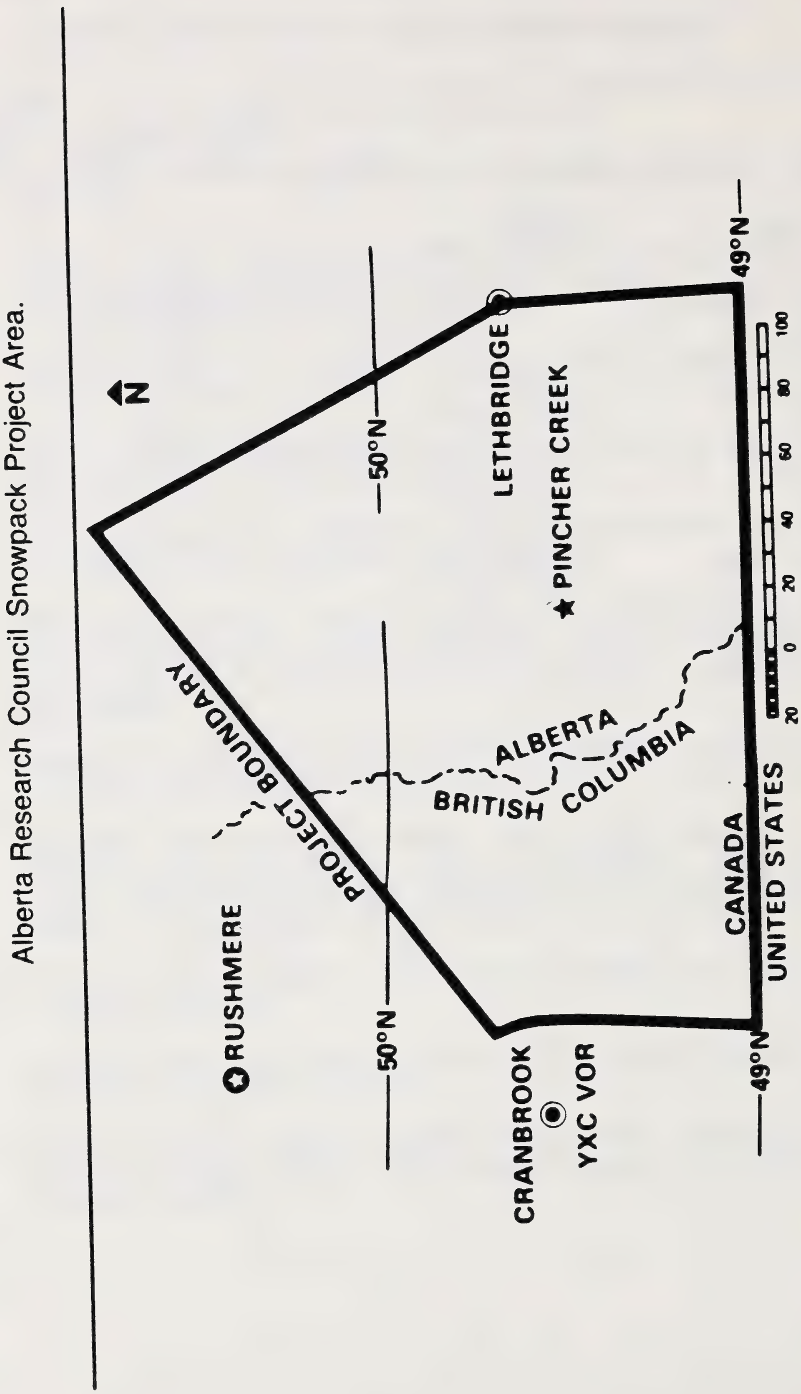


Figure 1. The Snow Project area. Research aircraft flights were made along specific tracks within the project boundary to obtain in situ observations of the cloud hydrometeors and thermodynamic structure.

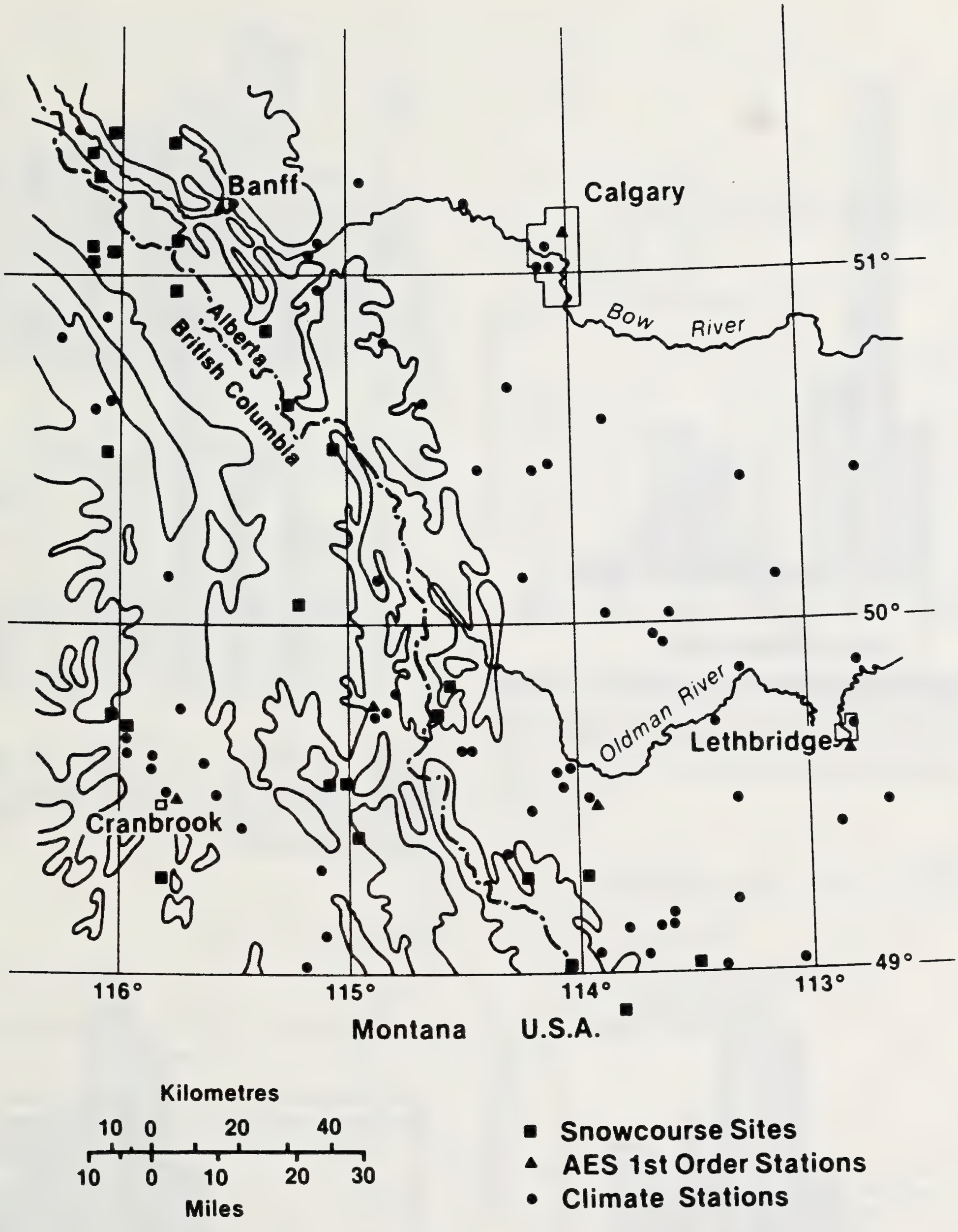


Figure 2. Network of A.E.S. climate stations and provincial snow survey sites in the southern Canadian Rockies area.

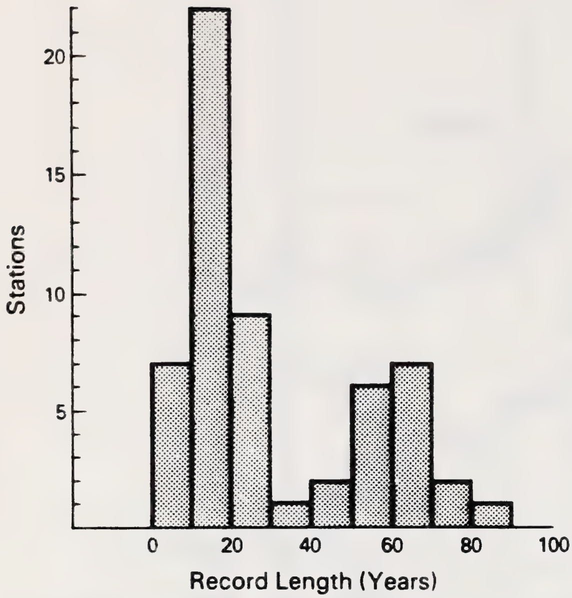


Figure 3. Frequency of record length for 57 A.E.S. mountain climate stations.

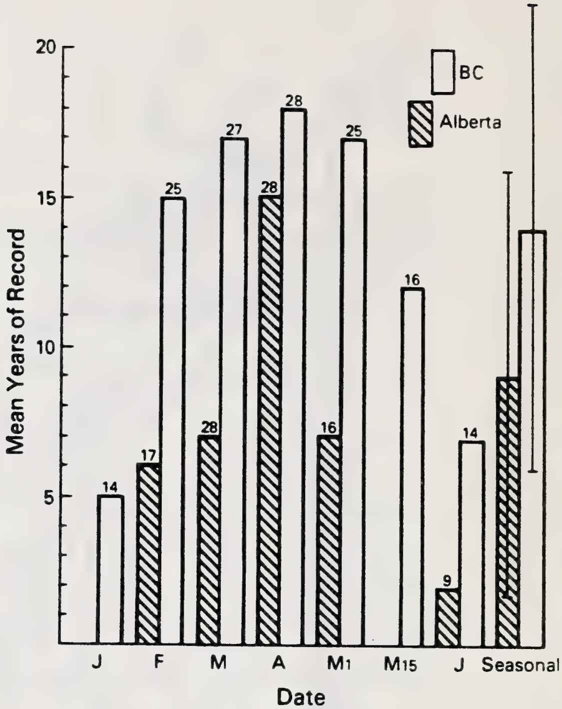


Figure 4. Average record length of Alberta and British Columbia snow survey courses throughout measurement season. The seasonal standard deviations is also given.

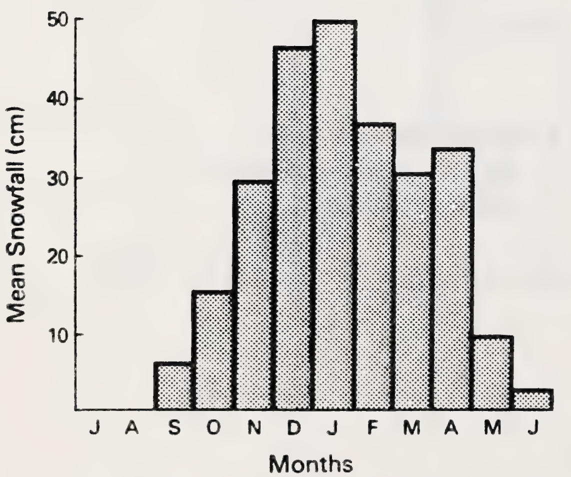


Figure 5. Average monthly snowfall over the year for 57 mountain A.E.S. climate stations.

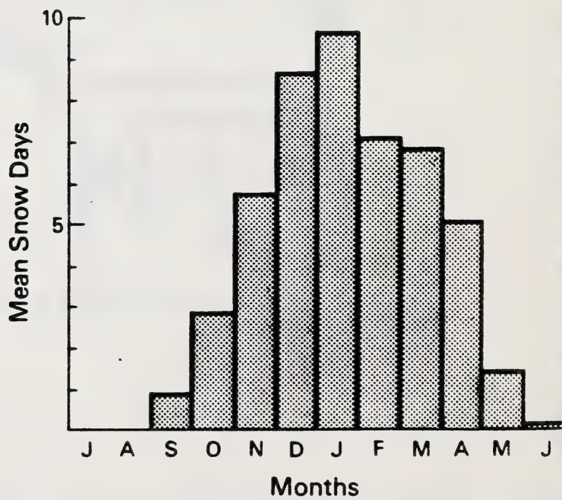
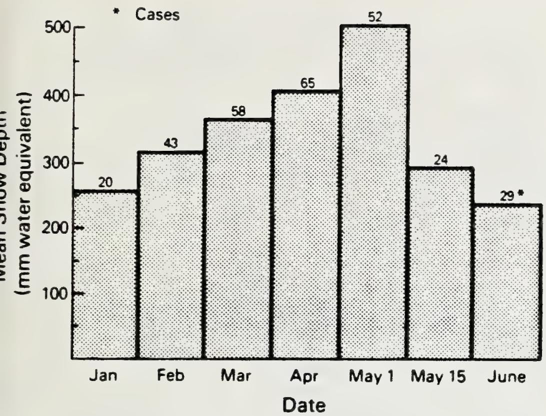
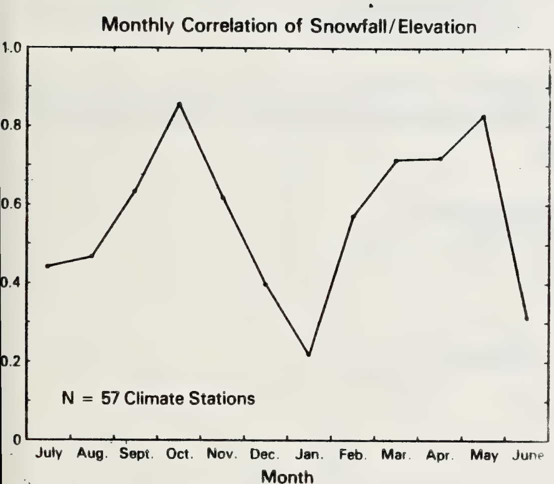


Figure 6. Average monthly number of snowfall-days over the year for 57 mountain A.E.S. climate stations.



igure 7. Average snow water equivalent over the
neasurement season for 70 Alberta, B.C. and Montana
now courses.



igure 9. Seasonal variation of the correlation be-
een average monthly snowfall and station elevation
r 57 A.E.S. climate stations.

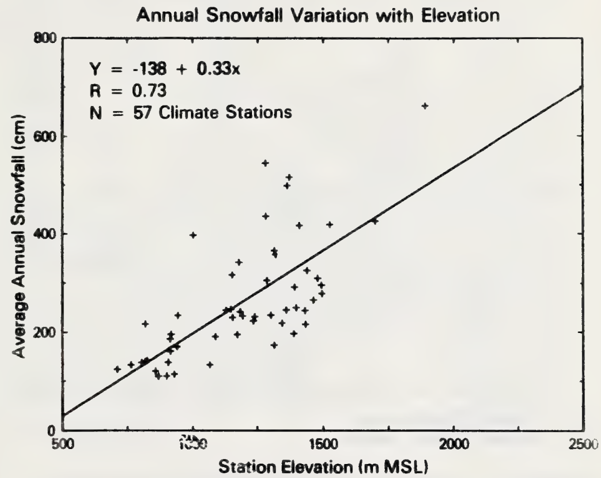


Figure 8. Variation of average annual snowfall with station elevation for 57 mountain A.E.S. climate stations. The calculated linear regression least squares fit and correlation coefficient are also shown.

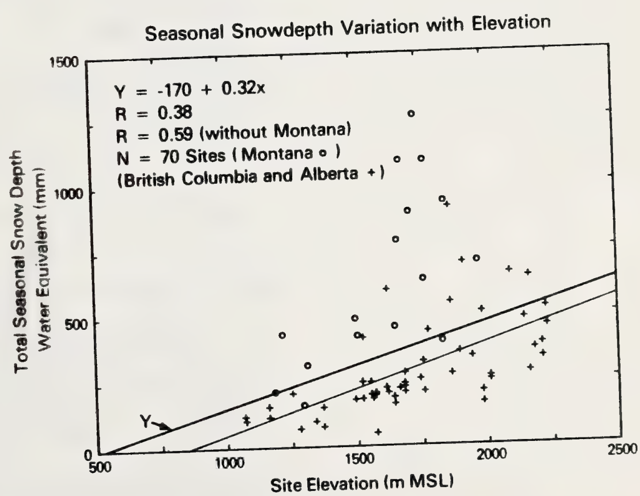


Figure 10. Seasonal variation of average snow water equivalent with elevation for 70 Alberta, B.C. and Montana snow courses. Linear regression lines and correlation coefficients calculated both with and without the Montana data are also shown.

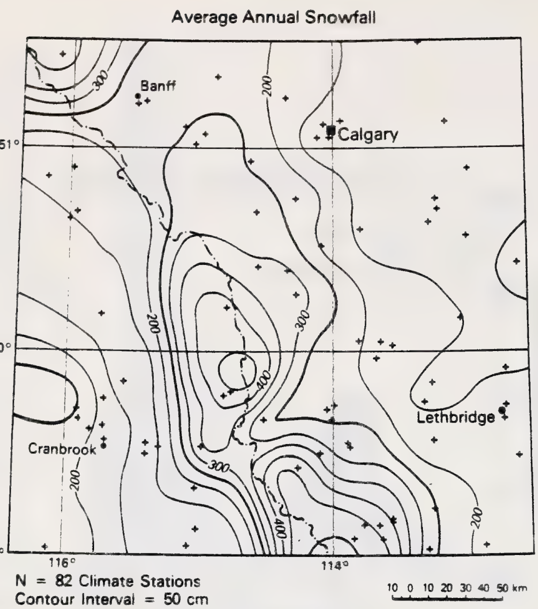


Figure 11. Average annual snowfall for general project area (82 A.E.S. climate stations).

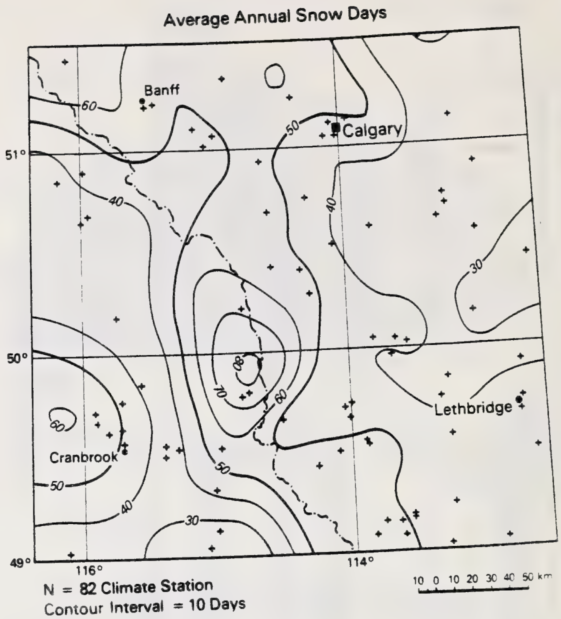


Figure 12. Average number of annual snow days for general project area (82 A.E.S. climate stations).

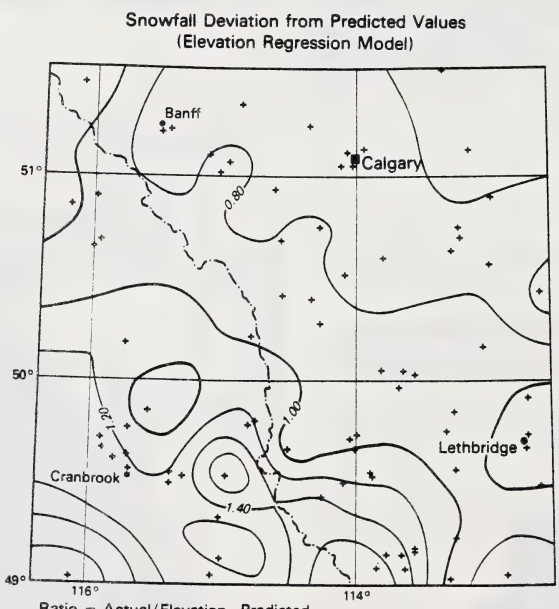


Figure 13. Ratio of actual annual snowfall to elevation regression model predicted annual snowfall for general project area (82 A.E.S. climate stations).

AGENCY REPORTS

ATMOSPHERIC ENVIRONMENT SERVICE

A. Mann
Environment Canada
6325 - 103 Street
Edmonton, Alberta

Scientific Services Division

The total number of climatological stations remained basically unchanged from that of the previous year. A total of 13 new stations were added to the AES Western Regional network while 12 stations were closed. The observing program was expanded to include both temperature and precipitation at 7 stations. Supplementary wind observations were added to the Vauxhall program. The seasonal observing progrm at Vauxhall CDA was also extended to provide coverage throughout the full year. A list of station additions, deletions and program changes is attached.

CLIMATOLOGICAL STATION UPDATE - WESTERN REGION

JANUARY-DECEMBER 1983

New Stations	Basin	Latitude	Longitude	Date	Program
Arneson	Red Deer	51 14	110 03	8304	P
Brant	S. Sask.	50 27	113 30	8304	P
Castle Mtn Village	Rocky Mtns.	51 16	115 55	8306	TP
Contracosta Lake	N. Sask.	51 46	111 33	8306	P
Dickson Dam	Red Deer	52 03	114 13	8304	TP
Dowling Lake	Red Deer	51 44	111 55	8306	P
Gibbons	N. Sask.	53 49	113 10	8311	P
Gooseberry Lake	N. Sask.	52 07	111 42	8304	P
Hinton Blue Lake Centr	Atha.	53 29	117 48	8306	TP
Monitor	N. Sask.	52 01	110 34	8304	P
Oakland Lake	Red Deer	51 23	111 57	8311	P
Ricinus	N. Sask.	52 05	115 00	8307	P
Mayo Road	YT	60 52	135 11	8305	TP

Station Closures	Basin	Latitude	Longitude	Date	Program
Acme	Red Deer	51 30	113 25	8301	TP
Big Valley West	Red Deer	52 02	112 58	8304	P
Carbon	Red Deer	51 29	113 09	8301	P
Fisher Creek	S. Sask.	50 48	114 30	8305	P
Hoadley	Red Deer	52 51	114 13	8303	P
Magnolia	Atha.	53 35	114 53	8304	P
Mayerthorpe	Atha.	53 58	115 07	8311	P
Pine Ridge	N. Sask.	54 05	112 16	8310	TP
Pollockville	Red Der	51 05	111 36	8311	TP
Sounding Creek	Peace	58 01	116 35	8305	TP
Steephill Creek	Peace	58 01	116 35	8305	TP
Mile 11 Carcross Rd.	YT	60 27	134 50	8310	TP

Program Changes	Basin	Latitude	Longitude	Date	Program
Atlee	Red Deer	50 49	110 57	8309	P to TP
Big Stone	Red Deer	51 10	111 12	8311	P to TP
Blood Indian Creek	Red Deer	50 55	111 04	8311	P to TP
Dewinton	S. Sask.	50 48	114 02	8309	TP to P
Hanna	Red Deer	51 35	111 51	8311	P to TP
Scapa	Red Deer	51 52	112 01	8309	P to TP
Two Bar Lake	Red Deer	51 17	112 33	8305	P to TP
Vauxhall CDA#	S. Sask.	50 03	112 08	8306	TPESWRGN*
Writing on Stone Park	Milk	49 05	111 37	8308	P to TP

The following special reports and climatological studies were undertaken by Scientific Services personnel:

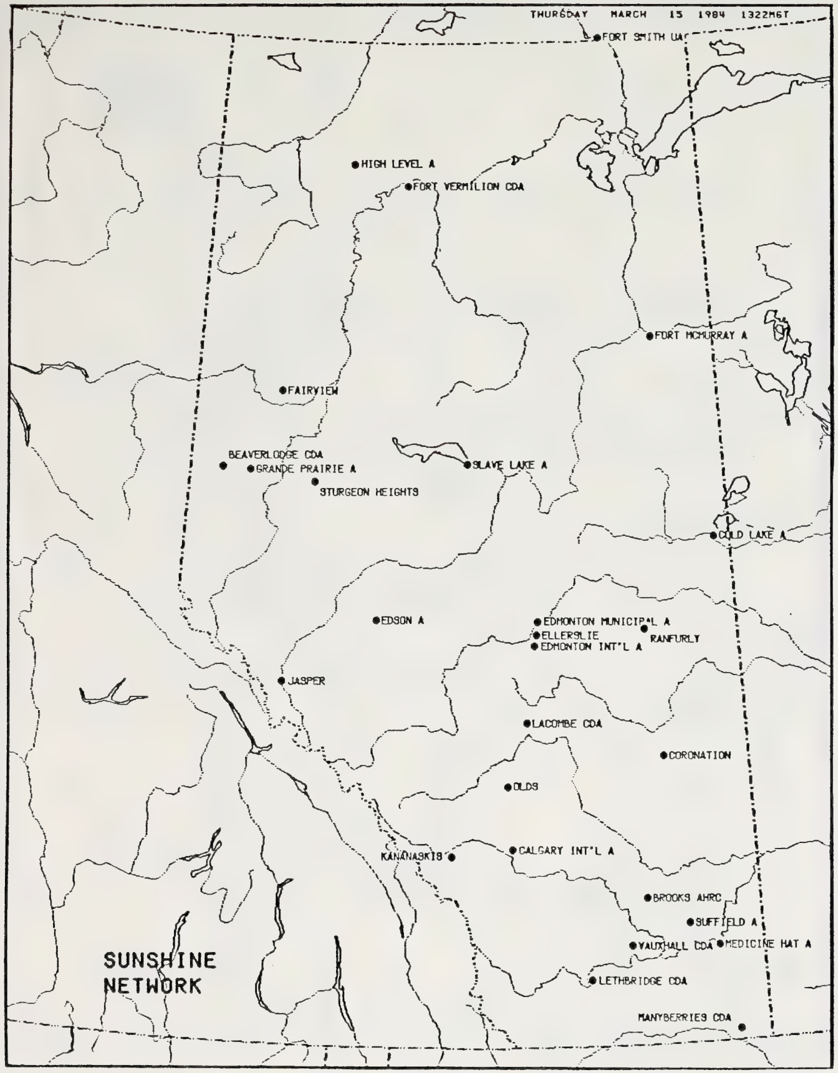
Climate of the Yukon North Slopes - started
Artificial Ice Islands - completed
Flying Weather in Tuktoyaktuk - completed
Mackenzie River Basin Network - completed
Nahanni National Park Climatology - completed
Fort McMurray Area Weather - completed
Lesser Slave Lake 1983 Storm Studies - completed
Smoky/Peace River Basin Studies - under preparation
Climate of Edmonton - completed
Bassano Wind Study - completed
Marmot Creek Watershed Research - under preparation
Kananaskis Climatology - under preparation
Sulphur Deposition Modelling in Western Canada - final draft
Sulphur Deposition in Alberta - under preparation
Lodgepole trajectories - under preparation

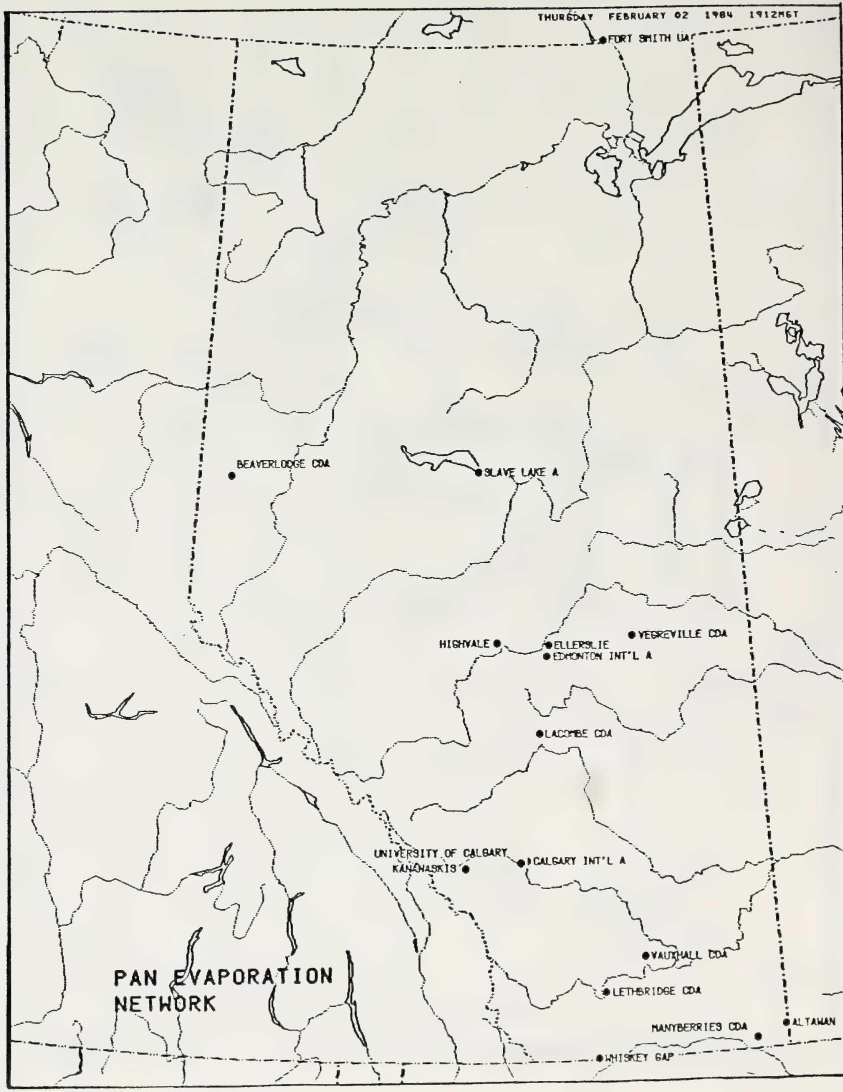
Canadian Climate Program Publications

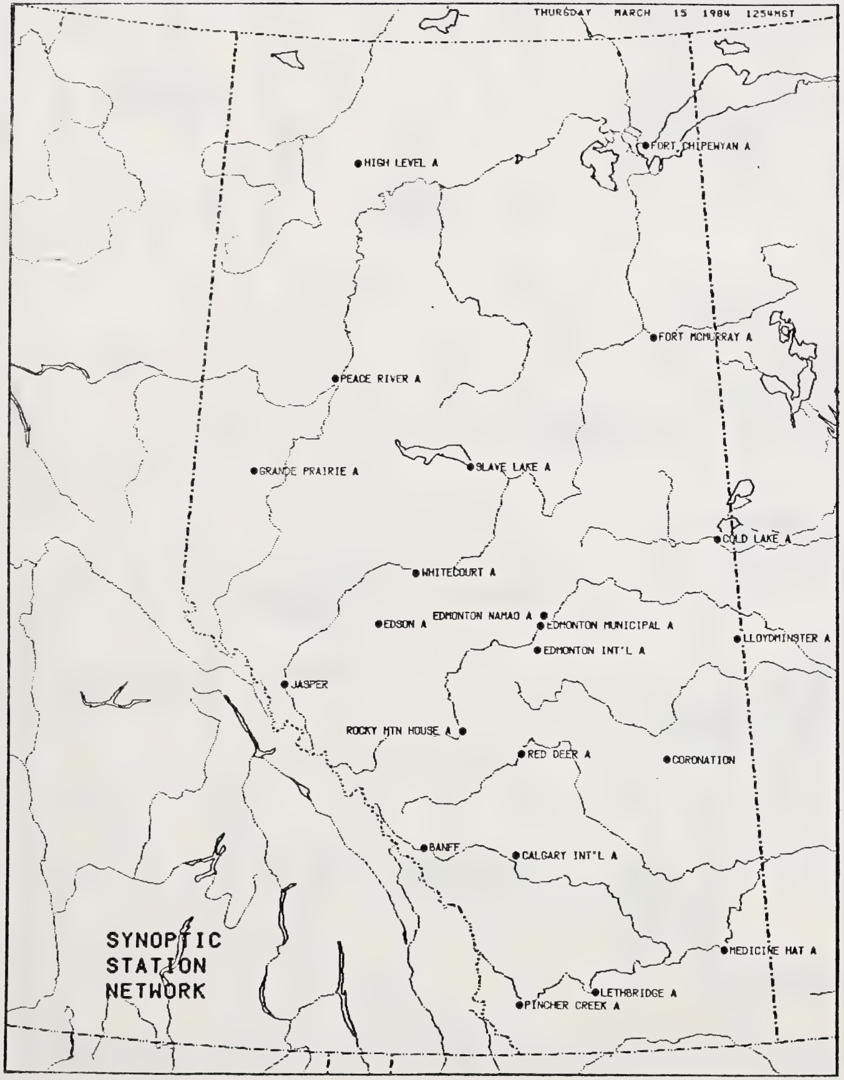
No new Canadian Climate Normals based on the 1959-80 period were published since Volume 7 - Sunshine. Volume 8 "Atmospheric Pressure, Temperature and Humidity" based on the hourly micro-fiche series is nearing completion and should be available within the next several months. Volume 9 "Soil Temperature, Lake Evaporation and Days With" is currently under preparation. Volume 10 has tentatively been assigned to Upper Air Climatology. This volume, however, is still in the planning stges and will likely not be published until early 1985.

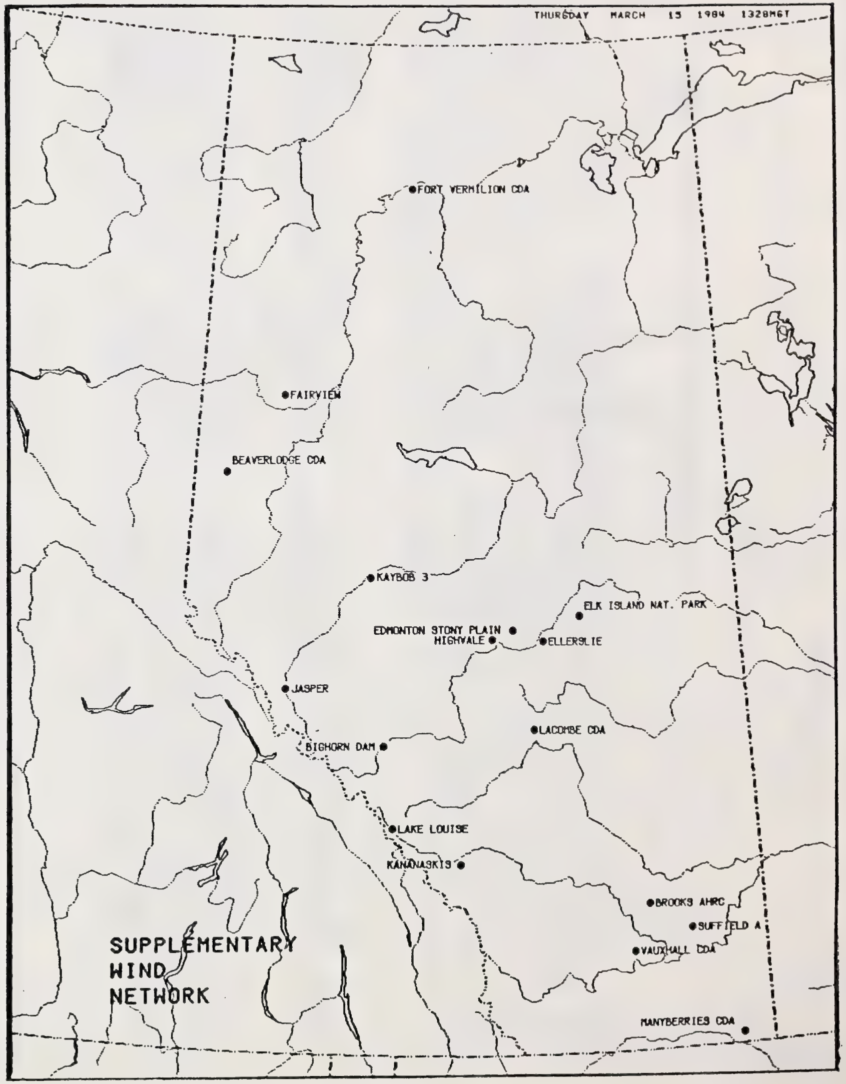
Temperatures and degree days, the first of the climatological map series have been completed and are being scheduled for printing.

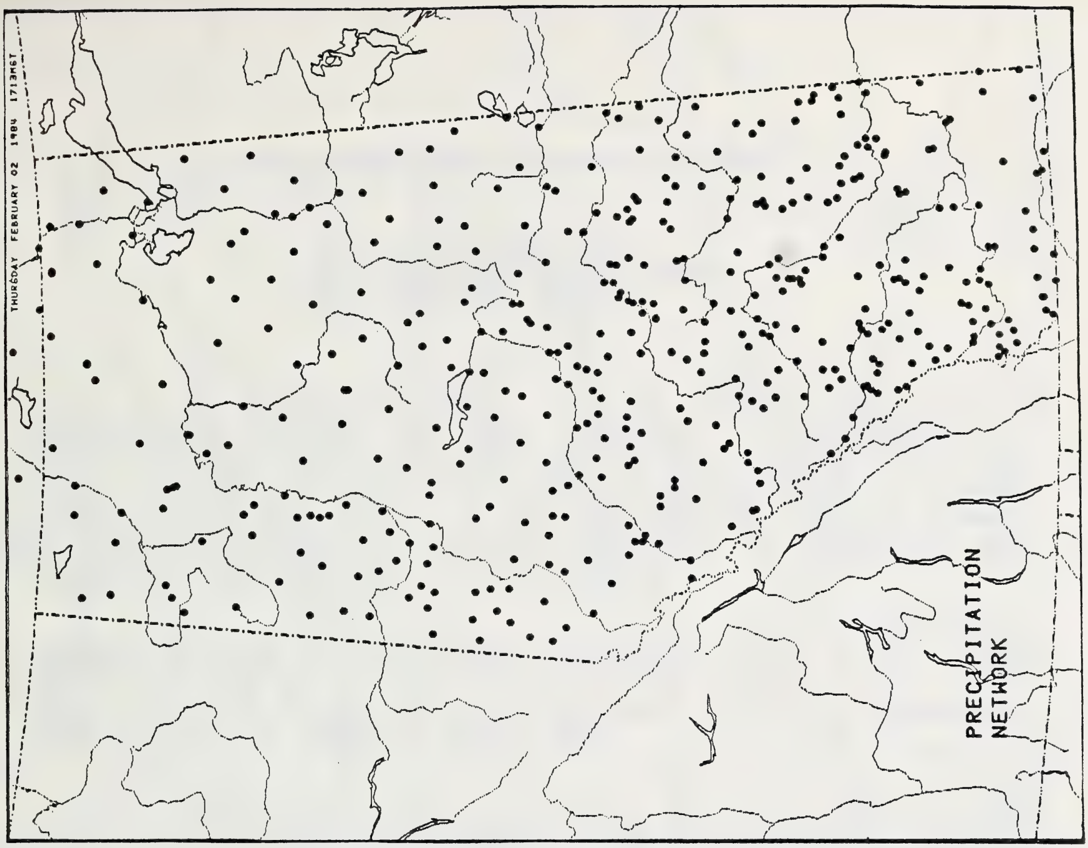
The Canadian Climate Centre has introduced a new "Principal Station Data" series. These contain new versions of many of the tables from the Hourly Data Summaries but with the addition of considerably more information on normals, extremes, frequencies and durations. PSDs will be compiled for approximately 150 principal stations across Canada during 1984-1985.


THURSDAY MARCH 15 1984 1322MGT
FORT SMITH UA
HIGH LEVEL A
FORT VERMILION CDA
FORT MCMURRAY A
FAIRVIEW
BEAVERLODGE CDA
GRANDE PRAIRIE A
STURGEON HEIGHTS
SLAVE LAKE A
COLD LAKE A
EDSON A
EDMONTON MUNICIPAL A
ELLERSLIE
EDMONTON INT'L A
RANFURLY
JASPER
LACOMBE CDA
CORONATION
OLDS
KANANASKIS
CALGARY INT'L A
BROOKS AHRC
SUFFIELD A
VAUXHALL CDA
MEDICINE HAT A
LETHBRIDGE CDA
MANYBERRIES CDA
SUNSHINE
NETWORK


THURSDAY FEBRUARY 02 1984 1912MGT
FORT SMITH UA
BEAVERLODGE CDA
SLAVE LAKE A
HIGHVALE
ELLERSLIE
EDMONTON INT'L A
VEGREVILLE CDA
LACOMBE CDA
UNIVERSITY OF CALGARY
KANANASKIS
CALGARY INT'L A
VAUXHALL CDA
LETHBRIDGE CDA
MANYBERRIES CDA
ALTAWAN
WHISKEY GAP
PAN EVAPORATION
NETWORK


THURSDAY MARCH 15 1984 1254MST
SYNOPTIC
STATION
NETWORK
HIGH LEVEL A
FORT CHIPEWYAN A
FORT MCMURRAY A
PEACE RIVER A
GRANDE PRAIRIE A
SLAVE LAKE A
COLD LAKE A
WHITECOURT A
EDSON A
EDMONTON NAMAO A
EDMONTON MUNICIPAL A
EDMONTON INT'L A
LLOYDMINSTER A
JASPER
ROCKY MTN HOUSE A
RED DEER A
CORONATION
BANFF
CALGARY INT'L A
MEDICINE HAT A
LETHBRIDGE A
PINCHER CREEK A


THURSDAY MARCH 15 1984 1328MST
SUPPLEMENTARY
WIND
NETWORK
FORT VERMILION CDA
FAIRVIEW
BEAVERLODGE CDA
KAYBOB 3
ELK ISLAND NAT. PARK
EDMONTON STONY PLAIN
HIGHVALE
ELLERSLIE
JASPER
LACOMBE CDA
BIGHORN DAM
LAKE LOUISE
KANANASKIS
BROOKS AHRC
SUFFIELD A
VAUXHALL CDA
MANYBERRIES CDA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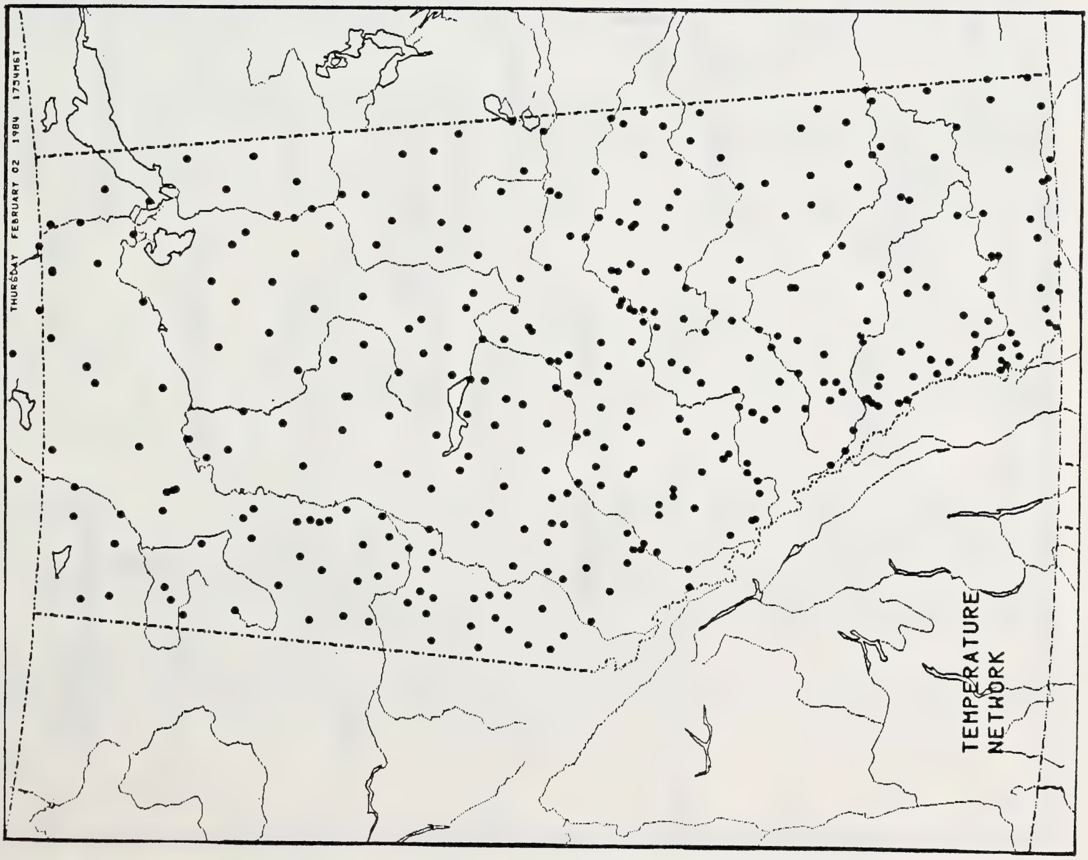
PRECIPITATION NETWORK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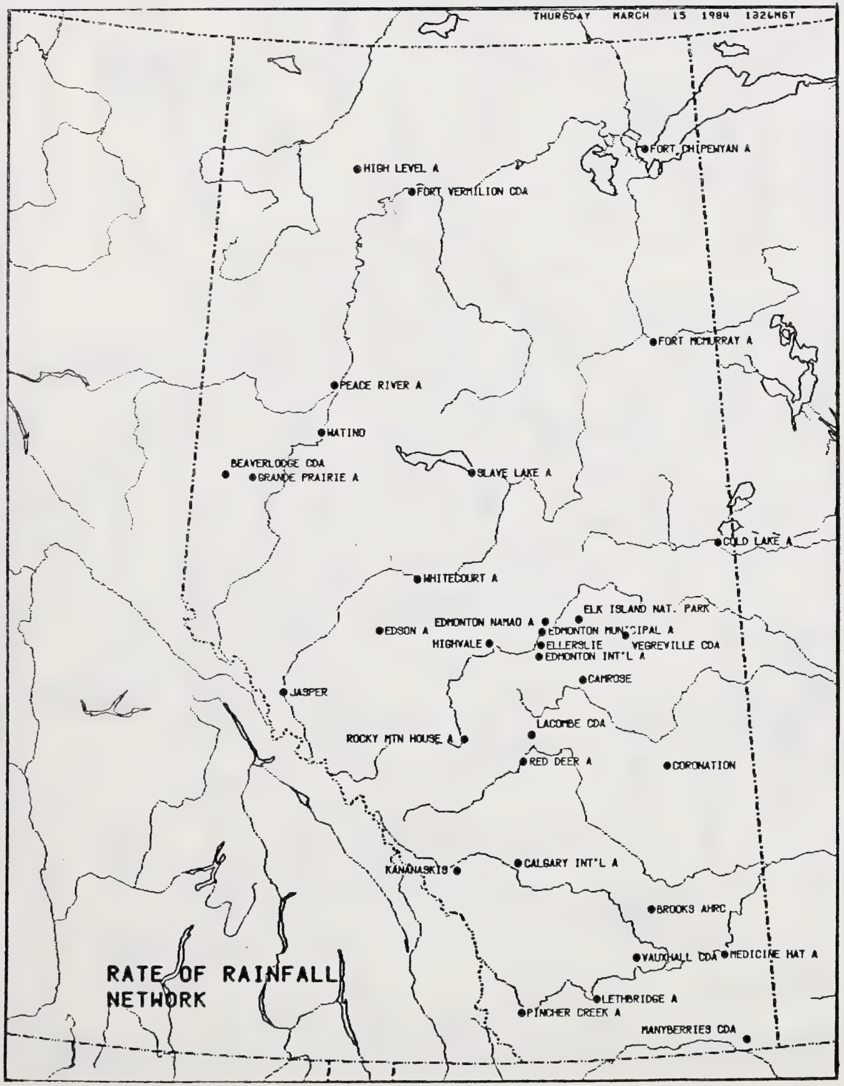
TEMPERATURE NETWORK


THURSDAY MARCH 15 1984 1324MST
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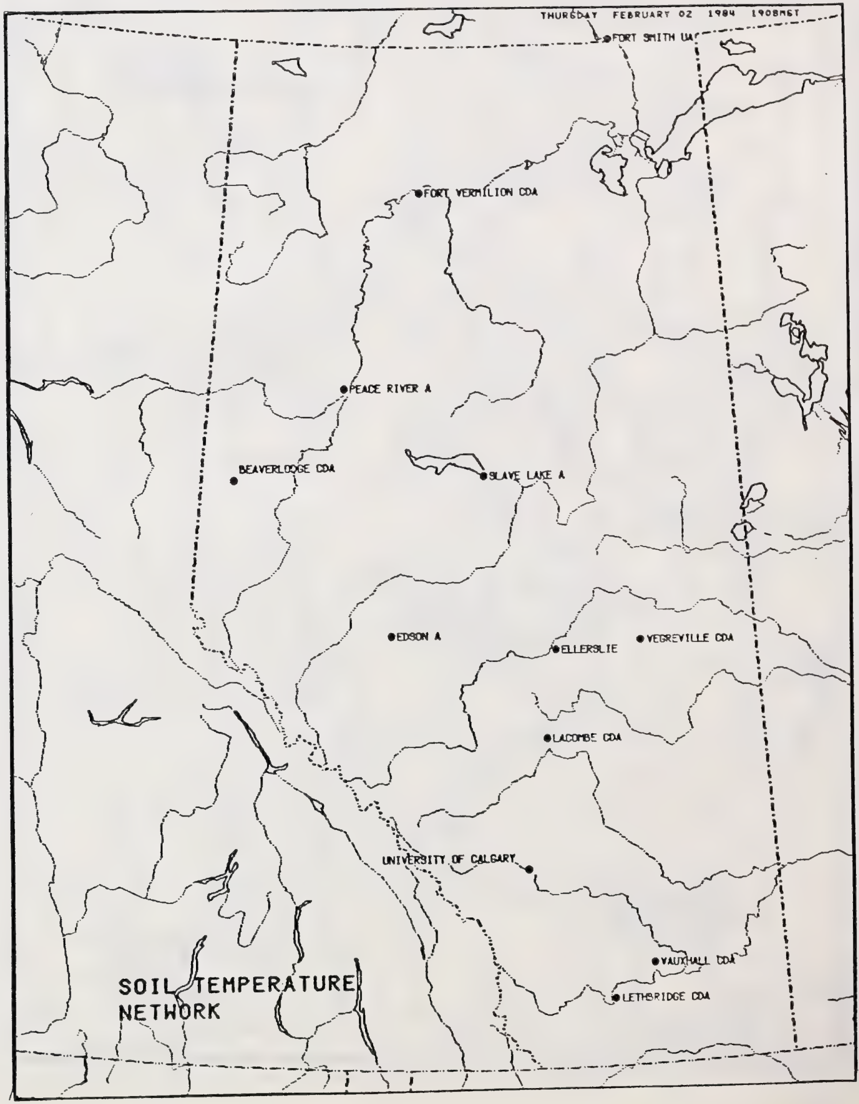
FORT VERMILION CDA
FORT CHIPEWYAN A
FORT MCMURRAY A
PEACE RIVER A
WATINO
BEAVERLODGE CDA
GRANDE PRAIRIE A
SLAVE LAKE A
COLD LAKE A
WHITECOURT A
ELK ISLAND NAT. PARK
EDMONTON NAMAO A
EDMONTON MUNICIPAL A
EDSON A
HIGHVALE
ELLERSLIE
VEGREVILLE CDA
EDMONTON INT'L A
CAMROSE
JASPER
LACOMBE CDA
ROCKY MTN HOUSE A
RED DEER A
CORONATION
KANANASKIS
CALGARY INT'L A
BROOKS AHRC
VAUXHALL CDA
MEDICINE HAT A
LETHBRIDGE A
PINCHER CREEK A
MANYBERRIES CDA
RATE OF RAINFALL NETWORK


THURSDAY FEBRUARY 02 1984 1908MST
FORT SMITH UA
FORT VERMILION CDA
PEACE RIVER A
BEAVERLODGE CDA
SLAVE LAKE A
EDSON A
ELLERSLIE
VEGREVILLE CDA
LACOMBE CDA
UNIVERSITY OF CALGARY
VAUXHALL CDA
LETHBRIDGE CDA
SOIL TEMPERATURE NETWORK

AGRICULTURE CANADA - ALBERTA SOIL SURVEY

Wayne Pettapiece
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Climate is an essential framework for the majority of our soils interpretations. Potential for arable agriculture is considered within a climatic parameter such as frost free and precipitation deficiency. Erosion and erodability consider wind velocity, spring runoff and duration and intensity of summer storms. We anticipate using more detailed climatic data, specifically daily and cumulative information, as we move into more detailed modelling procedures in the near future.

Our role is mainy as a user of climatic information, but we do collect some data as well. We set out small meteorological networks in our current survey areas monitoring, on a bi-weekly to monthly basis, soil temperatures and precipitation to extend AES network data.

A recently developed product which might be of interest to the climatological community is the computerization of soil survey information. It is based on a quarter section cell so is quite general. From this data we can produce maps of such factors as soil water holding capacity.

AGRICULTURE CANADA RESEARCH STATION - BEAVERLODGE

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Agriculture Canada, Research Station
Box 29
Beaverlodge, Alberta
TOH OCO

As in the past the research program for agrometeorology at the Beaverlodge Research Station continues to be centered on three main areas. These are: (1) the collection, processing and analysis of high quality meteorological observations, (2) the participation in cooperative research supporting other programs at the Research Station, and (3) the undertaking of specific projects relating to the assessment of the meteorological resources for agriculture in northwestern Canada.

With the operation of an acceptable program at the Beaverlodge Research station the emphasis on data collectoin is now being reorientated to both improve facilities at other established sites under Agriculture Canada Control and to establish new sites in areas of agricultural concern. We had hoped to be able to establish solar radiation monitoring equiopment at the Fort Vermillion Experimental Farm this past year, however, due to funding and labour limitations that proved impossible. We not anticipate that instrumentation for the measurement of global solar radiation and net all wave radiation will be installed this spring. In addition to the expansion and upgrading of this station we have been cooperating with Alberta Energy and Natural Resources in the establishment of five new sites in the area east of the town of Peace River. The names and locations of these sites have been reported elsewhere. Work in this area is continuing and several additional stations are anticipated for the coming year.

Due to the extensive impact of meteorology on other aspects of the agricultural sector approximately one half of the effort at the Beaverlodge Research Staton are directed towards cooperative studies. These range from the supply of climatological data for specific areas to conducting joint experiments to resolve particular agricultural problems. Some of the larger studies that the program is currently involved with are as follows:

1. Cereal and Oilseed Crops: Work is currently underway to assess the effects of various climatic parameters on a program of cereal and oilseed agronomy. This work includes such items as optimum dates of seeding, grain drying procedures and indices. Also, a program is underway to examine the effects of low soil temperature and its diurnal variation on the germination and emergency of canola.

2. Apiculture: Work is currently underway with other researchers in the fields of bee pathology and bee management in efforts to assess the

the effects of meteorological and climatological parameters on both the overwintering practices and pathology of honey bees. In addition, cooperation also exists with a forage seed physiologist in a continuing study on the pollination activities of the leafcutting bee Megachile rotundata as effected by meteorological conditions.

3. Forage Crops: A continuing program is still underway to assess the winter hardiness of alfalfa as it relates to meteorological conditions at four locations: Beaverlodge, Alberta; Kamloops, British Columbia; Melfort and Saskatoon, Saskatchewan. Several other slightly more minor programs are underway concerning such areas as the water relations of weeds and herbcide eficacy in forage seed crops and the quality and yield productivity of various forages.

   We anticipate that there will be an expansion of work involved with the assessment of the effects of meteorological parameters on plant pathology. Particular emphasis will be put on the brown girdling root rot complex affecting canola.

The meteorological resources which exist for agriculture in the Peace River region is a topic that continues to receive a great deal of attention from not only the public but other governmental agencies, and decision making bodies. In light of this the program at the Beaverlodge Research Station is attempting to accurately define what these resources are and their magnitude.

A data set comprising yield data from 1917 to the present has been assembled and will be used to assess the impact of various meteorological components such as precipitation timing on yield. Previously reported growth chamber/photo period research has been suspended due to limiation in the amount of growth chamber space available, however, plans are being formulated to replace these experiments with larger field experiments similar in scope.

A second series of growth chamber experiments are planned to investigate the effects of cool temperatures at specific growth stages on the yield of various crops species. It is felt that this may prove to be of equal or greater significance with some species than the occurrence of a late spring frost while the plant is vigorously growing.

Finally, in light of the overwhelming dominance of moisture related claims to the Hail and Crop Insurance Corporation, a study into crop water use under dryland agricultural conditions is continuing. This project has recently been expanded to cover a full crop rotation and examine peripheral aspects such as the role of fallowing and soil temperature conditions unser various cropped surfaces.

NORTHERN FOREST RESEARCH CENTRE

John M. Powell
Canadian Forestry Service
5320 - 122 Street
Edmonton, Alberta

Recent Activities

Two ENFOR (Energy from the Forest) studies have been published which relate to climate: (a) impact of climatic variation on biomas accumulation in the boreal forest zone: selected references, (b) how climate affects tree growth in the boreal forest. Work continues with the assistance of Forintek Canada Corporation, Vancouver, in dendroclimatological reconstruction. Tree rings from white spruce were collected from four further sample points in Alberta. Further analysis is being done with 600+ year old Douglas Fir tree ring samples from Banff to reconstruct the past climate of that area using the nearly 100 year climate record from Banff for calibration. This will also assist Forintek in further calibrating the over 600 year old Engelmann spruce record from the Columbia Icefields and shorter (300 year) records from Pevto Lake and Lake Louise.

A water balance computer model was applied to data describing the climatic-streamflow relationship existing over the entire Marmot Experimental Basin in an attempt to determine if the effect of the Cabin subbasin cutting was evident at the main streamgauge. This was not successful. A report on the winter climate of Marmot (Mt. Allen) is in preparation and should be published this summer. A report is also in review on "Clearing aspen from rangeland enhances soil water regime" which relates to work carried out in the Porcupine Hills area, and especially Streeter Basin.

Soil moisture and forest microclimate instrumentation were installed in clearings at the James River forest microclimate study site in preparation for a study of evaporation from the low vegetation or soil (in summer) and snow (in winter) in clearings. This study is planned to commence in 1984.

Field data on thermal diffisivity and moisture content of green wood have been collected. Preliminary analysis indicates that theoretically derived moisture contents are consistently low by about 20%. This consistency means that the technique will likely be suitble for in situ dynamic determinations of wood moisture content with only minimal calibration.

Analysis continued on aspects of frost damage in nursery container seedlings. A forest management note was published on "Optimizing containerized conifer seedling production in the Prairie Region" and one on

"Field storage of containerized conifer seedlings". A report is now planned to illustrate frost damage diagnostic symptoms.

Progress continued to be made with INA isolations from bark and leaf surfaces of plants and from irrigation water, with identifications to genus or species. A paper is being prepared on bacterial ice nucleating patterns, chemical, morphological and INA changes.

One paper has been published on the contribution of Richmond Longley in the study of climate variation, and another is to be published this month on the History and Development of the Canadian Climate Program (CCP). A paper is under review of climatic variation in the boreal forest zone of the prairies and NWT based on the period of record. Work is continuing on analyzing the growing season climate for pine and spruce seedlings on four clearcut blocks in the Hinton area.

Three user agency-oriented publications associated with the Canadian Forestry Fire Danger Rating System, and three articles dealing with the behavior of experimental and wild fires in relation to the Canadian Forest Fire Weather Index components were published. A paper was presented at the 7th Conference on Fire and Forest Meteorology documenting the environmental conditions associated with a "blowup fire" in east-central Alberta during the 1980 fire season. A report is nearing completion on the forest fire environment of Pukaskwa National Park. A fire weather/behavior seminar featuring five presentations were held in conjunction with the annual meeting of the Western Region Fire Weather Committee in March 1983.

Publications

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Zalasky, H. 1983. Field storage of containerized conifer seedlings. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alta. For. Manage. Note 20.

Zalasky, H. 1983. Optimizing containerized conifer seedling production in the Prairie Region. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alta. For. Manage. Note 23.

Zoltai, S.C. and F.C. Pollett. 1983. Wetlands in Canada: their classification, distribution, and use. Chapter 8. In A.J.P. Gore (ed.) Mires, swamp, bog, fen and moor, B. Regional studies. Elsevier Scientific Publ. Co., Amsterdam.

ALBERTA AGRICULTURE - CONSERVATION AND DEVELOPMENT

Conrad Gietz
Edmonton, Alberta

Frost Protection

A one-year "Farming for the Future" research project is underway to test the effectiveness of various ice nucleation inhibitors on canola and field beans. The project is about mid-term and initial results appear to be mixed. There was an interesting result in other tests where a number of common barley varieties were compared as to freezing susceptibility. Distinct varietal differences were measured, suggesting that farmers may soon be able to make informed choices to reduce frost risk. Proposals to test the full range of Alberta varieties are being drafted.

Soil Moisture

A map of estimated soil moisture reserves for 1984 carried through the winter has been drafted and will be distributed to elevator points and extension staff. A study was completed showing the effects of fall precipitation on yields of barley planted on stubble.

Climate Change

An assessment of likely/possible impacts of climate change on Alberta is nearing completion.

ALBERTA FOREST SERVICE

Dahl Harvey
Alberta Forest Service
Alberta Energy and Natural Resources
Edmonton, Alberta

The 1983 fire season in Alberta was much less severe than in previous years. There were 756 fires and 2700 hectares were burned.

All seven field units of the Lightning Location and Protection system were in operation this last summer. Remote display processors were in place and operating at our ten Forest Headquarters. However, there are still development problems with the LLP system. The 1983 experience indicates that the data from this system definitely will be of benefit in locating lightning and fires. 1983, however, had relatively little dry lightning.

There were no major changes in the Alberta Forest Service weather data network. The AFS is continuing to provide the data to the AES for publication in the Monthly Record of Meteorological Observations in Western Canada.

A selection of AFS stations are operating as climatological stations again this winter.

Five automatic weather stations using the GOES satellite system of data transmission were in service this last summer. Two will be equipped with pressure sensors.

Five semi-automatic weather stations were used this summer to obtain weather reports from the valleys of the Bow-Crow Forest. A modest expansion of the semi-automatic network is anticipated for 1984.

Publications

Nimchuk, N. Wildfire Behavior Associated with Upper Ridge Breakdown. ENR Report No. T/50.

Harvey, D. and Janz, B. are completing a paper entitled. A comparison of Fire Weather Severity in Northern Alberta During the 1980 and 1981 Fire Seasons.

B. Janz is carrying out a study of the 1936 fires in Alberta.

ALBERTA HAIL AND CROP INSURANCE CORPORATION

I.S. Selirio
Bag Service #16
Lacombe, Alberta

Update of the Hay and Pasture Program

The Canada-Alberta Crop Insurance program for hay and pasture crops was offered again, in 1983, in the Counties of Camrose, Flagstaff, Lacombe, Paintearth, Ponoka, Red Deer, Stettler and Wetaskiwin; Improvement Districts #5, 6, 8 (south of the Bow River) and 10; Municipal Districts of Cardston, Foothills, Pincher Creek and Willow Creek, and Special Area 2 (western portion) and 4.

Under this weather-based program, production is simulated based on available soil moisture and weather factors. Participating farmers provided daily rainfall reports from 667 farms during the period May 1 to August 31. The Atmospheric Environment Service provided climatological station reports from 36 precipitation stations, 74 precipitation and temperature stations, and 14 sunshine stations during the period April 1 to October 31. The moisture observations were conducted on more than 100 farms in early spring and summer, and to a limited number of sites in late fall.

The summary of experience for 1983 is as follows: number of policy holders is 607; total acres insured is 106,299; actual liability is $5,805,135; premium provided by participating farmers is $377,558; matching premium provided by the Government of Canada is $377,558; number of claims because of drought is 574; and total awards paid is $1,718,120 which represents a loss of $2.28 for every $1.00 in total premium, or $4.56 for every $1.00 in premium paid by farmers.

For 1984, the area eligible for insurance will be expanded to include the Counties of Beaver, Minburn and Vermilion River; the Municipal Districts of Acadia, Provost and Wainwright; and all of Special Area 2 (north of the Red Deer River) and 3.

Field Hay Drying Project

A study to determine the time required to field-dry hay as a function of weather was initiated in 1983. Moisture content of a hay swath was determined during cutting and every day thereafter until the hay was baled. In 1983, measurements were done during the month of July on eight farms in west-central Alberta. The period of measurements ranged from two days to eleven days because of the weather, particularly rain. The study will continue in 1984. The objective of this study is to assess weather-based simulation techniques like FHAYD (Dyer and Brown, 1977 Agric. Meteorol. 18: 37-48) for possible applications in hay quality insurance.

RESOURCE EVALUATION AND PLANNING DIVISION
ALBERTA ENERGY AND NATURAL RESOURCES

Serge Dupuis

New climatic networks were established near Cadotte Lake and near Alder Flats. Major networks in the Peace continue to dominate our data gathering activties.

A move towards automating data gathering by using solid state based "datapods" has been initiated. It is anticipated to reduce the requirements for regular maintenance and manually intensive data extraction.

Preliminary analysis of 5 years database in the Fort Vermilion area has produced interesting results. Procedures to map the data to a fine scale required for land use planning are still being developed. A stronger link between climate data and its uses in agriculture potential is still required to complete the agroclimatic mapping project.

The Climate Data Management System has been fully implemented. Normalization of short term data to long term averages has been successfully tested. The system is also used to integrate data from other agencies as required. Data from our networks can now be made available in standard AES format, on request.

ENVIRONMENTAL PROTECTION SERVICES
ALBERTA ENVIRONMENT

Bonnie L. Magill
Research Management Division

During 1983, Alberta Environment continued to support research and monitoring activities related to air quality and meteorology. As a component of a comprehensive study to determine the stability of a rock mass on Turtle Mountain, a weather station was installed on the peak to (i) characterize meteorological conditons and (ii) investigate the possible relationship between meteorological conditions and rock stability. Studies to assess air quality and to synthesize acoustic radar data for Edmonton to facilitate the development of an air pollution/dispersion climatology were continued. The analyses of data collected in previous years pertaining to (i) gas diffusion in mountain valleys, (ii) hydrogen sulphide concentrations from a gas well blowout and (iii) concentratoins of trace organcs in the vicinity of various industrial facilities were completed. A project was initiated to identify (i) existing sources of solar radiatoin data collected and (ii) current applications and uses of the data.

The formation of the Alberta Climate Advisory Committee, whose function in part will be to advise the Canadian Climate Program of Alberta's needs/concerns related to climatology, was finalized. Climatic change was identified as one key area of concern. Chaired by personnel from the Environmental Protection Services, the Committee consists of representatives from the Federal/Provincial governments, industry and academia.

The Department maintained a high degree of involvement in acid deposition research including liaison with various Federal/Provincial governments and industry. In examining air pollutant-induced changes in the environment, air quality and atmospheric data must be closely interfaced with measured environmental responses. Accordingly an integrated research effort was designed to assess the short-/long-term environmental affects of acid-forming emissions to terrestrial ecosystems. As an integral component of this research effort projects were undertaken to collect integrated data to document and quantify dry and wet deposition and to investigate the transformation, dispersion and transport of acid-forming emissions.

Publications

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Angle, R.P. **Urban Air Pollution Meteorology in Alberta Environment.** Presented at Urban Air Quality Workshop sponsored by Research Management Division, Alberta Environment, Edmonton, Alberta, October 17-18, 1983, 19 pp.

Gray, J.M.L. and G.G. Goyer. 1983. **Injection of Silver Iodide from Cloud Seeding into the Atmosphere of Central Alberta.** Prep. for the Research Management Division by Alberta Research Council. RMD Report 83/20, 34 pp.

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Hrudey, S.E., B.G. Kratochvil, R.R. Orford, J.W. Markham, and R.K. Shaw. **Scientific Methodology Assessment Committee Report.** July, 1983, 50 pp.

Krouse, H.R. and J.W. Case. 1983. **Sulphur Isotope Abundances in the Environment and their Relation to Long-Term Sour Gas Flaring Near Valleyview, Alberta.** Pre. for the Research Management Division by the Department of Physics, University of Calgary. RMD Report 83/18, 110 pp.

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Peake, E. 1983. **Peroxacetyl Nitrate in the Calgary Atmosphere - Final Report.** Prep. for the Research Management Division by the Kananaskis Centre for Environmental Research, University of Calgary. RMD Report 83/24, 257 pp.

Sakiyama, S.K. **Numerical Modelling and Field Verification for the Shell Moose Mountain Sour Gas Project.** February 1983, 97 pp.

Sciex, Ltd. **Air Quality Surveys in Alberta Using the TAGA™ 3000 Mobile Laboratory.** Prepared for Pollution Control Division. February, 1983. 120 pp.

Strosher, M.T. **Trace Organic Compounds in the Atmosphere Near Industrial Development.** Prepared by Kananaskis Centre for Environmental Research, prepared for Alberta Environment. February, 1983. 53 pp.

Whittaker, J.D., R.P. Angle, D.J. Wilson, and M.G. Choukalow. **Risk-based Zoning for Toxic-gas Pipeline.** Risk Analysis 2(3), 163-169.

Wilson, D.J. and B.W. Simms. **Exposure Time Effects on Concentration Fluctuations in Plumes.** November 1983, 163 pp.

ATMOSPHERIC SCIENCES DEPARTMENT
ALBERTA RESEARCH COUNCIL

F.D. Barlow and R.K.W. Wong
700, 4445 Calgary Trail South
Edmonton, Alberta

The Atmospheric Sciences Department (ASD) is conducting a preliminary study into the possible increase of the southern Alberta water supply by augmenting the snowpack in the Rockies. The main objective of this initial study is to assess the modification potential of winter snow clouds by making in-situ measurements of the cloud physics using the ARC/INTERA research aircraft. Four short (2 week) field programs have been completed and included numerous measurements within snow cloud systems with additional support data provided by ARC upper air stations. Preliminary results indicate a possible modification potential.

An additional component to the snowpack project is a winter precipitation climatology study that has been recently initiated. The study will focus on the analysis of daily snowfall data using archived AES climate and upper air data. A principal goal is to relate snowfall characteristics with upper air temperature, moisture and wind conditions.

ASD also continued its efforts in other areas of weather modification in central Alberta. Activities included radar observations of severe storms, cloud physics measurements using instrumented aircraft and time-resolved ground measurements of hailstones. There were also upper air temperature and humidity measurements and ground measurements of rainfall.

Visible and infrared GOES satellite data, archived in the United States, can now be processed at ASD. The analysis of the data, part of the RAINSAT program, is directed towards examining the characteristics of precipitating clouds and examining how well these and other clouds can be distinguished on the basis of satellite data. Quantitative comparison with radar data is underway. Incorporation of maps of the synoptic index of convection (SC4) is being examined.

Aircraft measurements of gas emissions were also conducted in the Fort McMurray area as part of a continuing project for Alberta Environment. The objetives of this study are: (1) to measure the transport and dispersion of $SO2$ emissions, (2) to determine the transformation rate of $SO2$ to $SO4$, and (3) to document the redistribution and rate of removal of pollutants from the atmosphere by clouds and precipitation.

Other activities included the continued development and testing of a computer system to provide real-time measured precipitation data to the Alberta River Forecast Centre.

UNIVERSITY OF ALBERTA
METEOROLOGY DIVISION
AND
INSTITUTE OF EARTH AND PLANETARY PHYSICS

Urban Valley Airflow and Air-Pollution Studies

K.D. Hage, R. Wong and L. Stovel

A computer model was developed by L. Stovel for simulating time-dependent wind and temperature fields resulting from surface radiational cooling at night in a small valley. The model was successful in reproducing quasi-steady-state recirculation flows near-surface wind and temperature profiles, in close agreement with observations.

R. Wong continued development of a computer simulation model for wind, temperature and pollutant concentration fields in a valley of arbitrary shape. He clarified in a significant way the formulation of the hydrostatic approximation for terrain-following coordinates. In addition, he devised a full set of diagnostic relations for testing conservation of mass, momentum and energy in his finite-difference model. These tests have proved invaluable in the search for model formulation error and inconsistencies.

Atmospheric Physics

E. Lozowski, G. Strong, B. Kochtubajda, F. Finstad and Z. Misztal

E. Lozowski and E. Gates (Mechanical Engineering) have been carrying out wind-tunnel icing experiments. Comparisons between the experimental observations and the predictions of a new time-dependent rime icing model are very encouraging. Miss K. Finstad has begun work on the further development of an airfoil icing model devised by M. Oleskiw, B. Kochtubajda has completed a thesis on the sublimation of dry ice. He has recently made use of his results in connection wth cloud-seeding experiments undertaken by the Alberta Research Council. Z. Misztal is analysing air-pollution and precipitation measurements obtained during the Intensive Sulphate Study in Eastern Canada in August, 1976. G. Strong is continuing his work on the forecasting of convective weather, and the dynamical interaction between the synoptic and mesoscales of motion.

Meso-Scale and Satellite Meteorology

E.R. Reinelt, D. Phillips, R. Goodson and C. Sackiw

D. Phillips has completed a paper on airflow over mountains with barrier profiles of different aspect and orientation. He has derived closed-form, analytial solutions for surface-pressure and wind fields generated by mountains with elliptical bases and cross-sections. These solutions enabled him to explorate the effects of barrier profile on wind and pressure at all transitional stages between the fully tree-dimensional circular, bell-shaped mountain, and the two-dimensional, limiting case of an infinitely long ridge.

R. Goodson is completing a study on the use of high-resolution satellite data for discriminating between precipitating and non-precipitating convective clouds in Central Alberta. Temperature and brightness maps have been deduced from satellite imagery, and correlated with rainfall collected in the standard gauges of the climate station network.

C. Sackiw is investigating the cohesiveness of upper-air soundings in space and time, by using pressure, temperature and wind data obtained in serial releases of radiosonde balloons. The principal aim is the design of an optimum upper-air network in hail-prone Central Alberta, capable of detecting and tracking atmospheric systems on a scale of a few kilometres.

E.R. Reinelt has investigated the usefulnes of 850-mb level streamline charts for weather analysis and forecasting in the Rocky Mountains. He has found that the 850-mb chart, augmented by terrain contours and local wind reports, is well suited for the depiction of meso-scale phenomena and short-range prediction in mountainous regions.

Industrial Meteorology

R.B. Charlton

Samples of snow falling from man-made cloud and fog have been collected during the 1982/83 winter in the petrochemical district of Edmonton, and subjected to chemical analysis. Snowfall rates were generally very light, but under conditions of low temperature and high moisture content, the snow reduced visibility locally to 100 metres and made roadways slippery.

UNIVERSITY OF CALGARY REPORT

Dr. L.C. Nkimdirim and Dr. S.A. Harris send their regrets that they were unable to attend.

Continuing program of data collection with the acquisition of a Campbell Scientific CRT has added a much needed facility for data acquisition.

Physics Department are using a network of acoustic sounders in a network to study the inversion and pre-chinook conditions at Calgary; two monostatic and one Doppler system - AES weather office one monostatic to display inversions.

Student graduate studies (MSc):

1. The effects of chinook winds on air pollution: the case of Calgary, Alberta by Warren Graham.

2. Experimental validation of an exhaust fan technique for measuring the heat available from attached greenhouses for residential space heating by R.E. Leckie.

Dr. S.A. Harris - Perma Frost Project - Plateau Mtn. north to Ft. Nelson - temperature measurements - development of sensing and recording equipment for multiple sensors.

THE EFFECTS OF CHINOOK WINDS ON AIR POLLUTION CONCENTRATION: THE CASE OF CALGARY, ALBERTA

by

Warren Graham

Only during the past few years have there been studies concerning the chinook/air pollution relationship in Calgary and there is controversy surrounding this relationship which must be resolved.

Are chinooks a factor in causing poor air quality over Calgary? Does the impact upon pollution vary from chinook to chinook? What is the nature of the variability? Which weather variable contributes most to the variability? These are some of the questions that this study will attempt to answer. The objective, therefore, is to analyze and describe the relationship between chinooks and air pollution and to determine which weather variables have the biggest effect upon air pollution concentration.

Data for the study was collected during the winter months of 1982/83 and 1983/84. Radiosonde flights were used to collect weather data during pre-chinook, chinook, and non-chinook situations. Data on air pollution (mainly CO, NOx, and the AQI) was obtained from Alberta Environment. The data from the flights (about 45 in all) and from Alberta Environment will be correlated and analyzed.

The findings of the study should provide information on the variability of air pollution concentrations within and between pre-chinook, chinook and non-chinook situations. It is hoped that the findings will help explain the descrepancy in recent literature concerning the chinook/air pollution relationship.

EXPERIMENTAL VALIDATION OF AN EXHAUST FAN TECHNIQUE FOR MEASURING THE HEAT AVAILABLE FROM ATTACHED GREENHOUSES FOR RESIDUAL SPACE HEATING

MSC Research Project
R.E. Leckie
Committee on Resources and the Environment
University of Calgary

An exhaust fan technique designed to directly measure the amount of useful heat available from attached greenhouses is being investigated at the University of Calgary Weather Research Station. The solar conversion efficiencies of two identical greenhouse test cells are being measured by a proven heat loss coefficient technique and by the experimental exhaust fan technique respectively. The results from a series of comparative tests will be used to determine the accuracy of the exhaust fan method. The method will then be used to measure the amount of supplemental heat which can be supplied from a greenhouse to an attached residence.

Temperature, radiation and pressure monitoring is achieved with a micro-computer based data acquisition system. The computer is also used to perform the data analysis and has the capability of reducing the real time data to graphic form. The exhaust fan apparatus consists of a high capacity axivane fan which draws air in through the bottom of the test cell and exhaust through an ASME long radius flow nozzle mounted high on the rear wall of the test cell. The amount of heat extracted is calculated by measuring the flow rate through the nozzle and the temperature differential between the incoming and outgoing air.

BUSINESS MEETING

CHAIRMAN'S REPORT TO THE 8TH ANNUAL GENERAL MEETING OF THE ALBERTA CLIMATOLOGICAL ASSOCIATION

February 23, 1984

The Directors of the ACA in 1983 were:

Serge Dupuis	Alberta Energy and Natural Resources	Chairman
Avard Mann	Atmospheric Environment Service	Secretary
Bill Khunke	Alberta Environment	
Conrad Gietz	Alberta Agriculture	
Bob Charlton	University of Alberta	
Ray Wong	Alberta Research Council	

The Board of Directors met throughout the year, primarily to plan the publication of the proceedings and the organization of the annual meeting. The 1983 proceedings were published with funding from Alberta Agriculture.

Due to the popularity of past annual meetings, the general theme of Current Climatological Activity in Alberta was adopted again this year.

The mailing list for the Association has been updated and now includes over 200 entries. Interest from out-of-province has also been keen.

The Association renewed its incorporation as a Society in the Province of Alberta, no cost was incurred.

I look forward to serving the remainder of the term as your Chairman.

Serge Dupuis
February 20, 1984

REGISTERED ATTENDEES
8TH ANNUAL GENERAL MEETING
ALBERTA CLIMATOLOGICAL ASSOCIATION

February 23, 1984

Barlow, Rick	Atmospheric Sciences Department Alberta Research Council 700 Terrace Plaza 4445 Calgary Trail South Edmonton, Alberta T6H 5R7
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